DOCUMENT RESUME

ED 141 074 SE 022 505

TITLE	Handbook for Teachers. Science Education Programme for Africa.
INSTITUTION	Science Education Programme for Africa, Accra (Ghana).
SPONS AGENCY	Agency for International Development (Dept. of State), Washington, D.C.; Education Development Center, Inc., Newton, Mass.
PUB DATE	Sep 74
NOTE	385p.; For related documents, see SE 022 504-506; Photography may not reproduce well
AVAILABLE FROM	Science Education Programme for Africa (SEPA), P.O. Box 9169, Airport, Accra, Ghana, Africa (Free)
EDRS PRICE	MF-$0.83 HC-$20.75 Plus Postage.
DESCRIPTORS	Elementary Education; *Elementary School Science; *Instruction; Objectives; *Science Activities; Science Education; *Teacher Education; *Teaching Guides
IDENTIFIERS	*Africa; Science Education Programme for Africa

ABSTRACT

This handbook, prepared by the Science Education Programme for Africa (SEPA), provides materials designed to improve science teacher education in African countries. The handbook provides illustrations of how in-service teachers teach science, how children learn science, how adults relate to children, how some teachers prepare for the task of guiding children's learning, and information on the nature of science. Section I provides information on how the Handbook is to be used. Section II provides an idea of what it is to be engaged in science activities. Section III offers a variety of materials that can lead to integrated science activities and situations. Section IV gives illustrations of how this approach has worked, and can work, with students. Sections V and VI provide information on materials and approaches for teaching. (SL)

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ED141074

HANDBOOK FOR TEACHERS

Science Education Programme for Africa
SEPA
Accra, Ghana

September 1974

SE 022 505

This Handbook has been produced with funds provided by
the United States Agency for International Development
through Education Development Center, Newton, Massachusetts.

PREFACE

In the past decade, educators the world over have focussed their attention on the importance of the early years of the development of children. This increased awareness of the crucial role that education can play in a child's development is one of the factors that led to the establishment of the Science Education Programme for Africa (SEPA). SEPA, with its Secretariat offices in Accra, Ghana, has as one of its primary responsibilities, the stimulation and support of a range of efforts in the field of science education.

A variety of primary school materials, mostly in the form of Teachers' Guides, have been developed and modified by various African countries. It has been recognised by SEPA, however, that any new approach to working with children in the classroom can only become effective when teachers are both aware of and enthusiastic about the changes being advocated. Therefore, at this time, SEPA gives high priority to the development of innovative, as well as more effective, ways of training teachers, initially at the pre-service phase of teacher education.

This Handbook for Teachers is a part of a set of materials which, it is hoped, will contribute to the improvement of teacher education in African countries. Users of the Handbook are encouraged to think of the ideas presented as starting points, or nuclei, around which additional developments can take place in directions decided by the user according to his or her circumstances. Furthermore, it is hoped that users of the Handbook will communicate, through their local curriculum development centre, with the contributors to this version of the Handbook. Such communication can help to improve and expand future versions to the advantage of all primary school science teachers.

HANDBOOK FOR TEACHERS

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SECTION I

INTRODUCTION

Chapter 1: The Philosophy of the Activity Approach to Primary Science Education

Science and its applications permeate every aspect of our lives. For this reason it has been said that we need "scientifically and socially oriented policy makers, as well as scientifically oriented citizens."[1] Towards the realization of this goal, most African States have given a high priority to science education. The establishment of the Science Education Programme for Africa (SEPA) bears testimony to this commitment.

SEPA's approach to science education takes the view that science is a medium through which a child might develop his natural curiosity, his powers of observation and enquiry, and constructive attitudes to problem-solving and decision-making. These are fundamental qualities of an education which has particular relevance to the total African environment and which fosters the child's understanding of his world and his own potentialities. As such, at the primary level, the SEPA approach is in direct contrast to the subject-oriented, academic view of science. Instead, it cuts across subject barriers and rejects specialization in favour of an integration of the many areas of scientific knowledge, as well as an integration of the scientific method with the process of human development.

---

[1] Keynote Address by Professor A. Babs Fafunwa, University of Ife, Nigeria, delivered at the SEPA Teacher Training Materials Workshop, Nairobi, Kenya, August 1971.

The role of the teacher is central to the successful implementation of the SEPA approach in primary school classrooms. The main tasks of the teacher are to prepare materials, to coordinate the activities of the children, and to ask appropriate questions at the appropriate times. Continuously, the teacher must diagnose and appraise the children's efforts, their imagination, excitement, and frustrations. Some of the teacher's decisions affect individual children, while others affect the whole class. He/she must decide when to enter into, and when to withdraw from the children's enquiry conversations without interfering with their own tempo or direction. Drawing upon all available resources to enrich the children's experiences, the teacher can go beyond the normal curricular requirements.

The demands made on teachers by this approach have far-reaching implications for their pre-service as well as for their continuing education. While incorporating critical elements of scientific knowledge to build a broad competence base, the teacher's education should be experience-oriented. It should include education in community development, the many facets of education for leadership and, as such, would be characterized by a style compatible with the requirements of the roles they will play in their profession.

As a first step in the long-term process of effecting educational change, SEPA has decided to develop novel strategies and materials which can improve the pre-service phase of teacher education. If the process of effecting change by creating desirable attitudes takes place before the teacher begins service, the gains will be both more professional for the teacher and economical for the society. When young teachers become more flexible in their approach to education, they will be better able to deal with practical situations as they arise. SEPA has decided to make a modest contribution to this phase of teacher education by producing a Handbook for Teachers.

What this Handbook stands for can best be described by paraphrasing what Havelock[2] wrote in *Guide to Innovation in Education*: it does not tell what actions should be followed nor does it recommend a specific sequence of educative events ("This is left to the judgement of those responsible for the conduct of practice in a given situation"), but *it does provide* information on how some teachers-in-training do science, how some children do science, how some adults relate to children, and how some people prepare themselves for the task of guiding children's learning, as well as information on the nature of science. *It does not tell you* all you need to know about SEPA's approach to science education. Most of all, *it cannot replace* direct experience with the very "sophisticated understanding of the process which comes from years of experience" with many educational encounters in many situations.

The importance of direct experience in human development can be illustrated. The child goes to school with some knowledge and some skills already learned. The child has learned to walk by walking; he has learned to speak by speaking and by listening to others. He has taken a certain period of time to learn to do each of these satisfactorily. The process has been gradual, involving mistakes and setbacks; it has been necessary to go through many stages in the process. But in the end the child has mastered the skills and the knowledge.

---

[2] Havelock, R.G., *The Change Agent's Guide to Innovation in Education.* Educational Technology Publications, Inc., Englewood Cliffs, N.J., U.S.A. 1973.

At the primary school level, however, the child begins to learn formally in other ways. Observation is formalized as a method of learning; sometimes there is imitation and other times there is drill. Learning situations involving direct experience are not always so easy to create and the learning derived comes slowly. However, the old saying that "experience is the best teacher" remains true and we seek to keep it alive by directing our efforts toward allowing children to learn science through doing activities.

Children find this mode of learning natural, interesting and even exciting. They appreciate adult participation if that participation is in the form of guidance and encouragement rather than prescription. For the guidance to be effective, the guide (teacher) must be able to understand and to speak in the children's "language." She/he must have an awareness of how children view the world around them, of their capabilities at different stages of development and of their modes of thought.

Such knowledge is gained primarily through direct experience with children at work (and play). For this reason, those who would be teachers of young children must spend time talking with and observing children in order to gain awareness of the children's culture. Children, then, must learn about nature, about their environment, about the universe, by asking their own questions, by finding their own answers to their own questions, and, from day to day, build a foundation for their own future understanding of the world around them.

Adults have gone through this process for centuries and have worked out definite procedures for minimizing the inevitable wastage in time and energy. Children cannot always appreciate the need for saving time and energy. It would appear that intuitively they recognize that there is some value in taking a wrong path sometimes. So they prefer to carry out their explorations and find out for themselves the answers that adults, in order to save time and avoid mistakes, are so eager to provide.

When children are left to explore for themselves, it is possible that they quite often create situations full of possibilities for learning useful information, techniques, skills and ideas or concepts. There should be guidance to help the child exploit all such learning situations to the fullest. It is not intended that the materials or topics be thrown at the children and the teacher then leave them alone without interest or guidance until the end of the lesson.

It is believed that through learning science by SEPA's approach the child will build the habit of looking closely at his environment and asking questions of it. He will also gain the ability to frame his questions in ways that permit answers to be found through performing some experiments or activities of his own design. Even when some of the answers at times are to be found in books or papers in a library, it will be recognized as good practice to examine them for possible application to new or to special local circumstances. Most important, the child will be learning how to learn. For the key to the future progress of science is in the hands of today's children, as is the application of science in technology within our society.

Chapter 2: How the Handbook may be used

The reasons for producing this Handbook are several. They can be summarized, however, by stating the need for a text specifically directed to student teachers in African teacher training colleges. Because of more than a decade of innovation in science education, there has been a strongly felt need to bring together and expand the many ideas contributed by science and teacher educators over the past few years.

It is hoped that this Handbook will serve as a guide whenever you wish to carry out activities, or to improve your experiments by referring to readings or procedures. You do not have to begin at any particular point in the Handbook. Nor is it intended that you follow a linear progression in going through the suggested exercises or activities. You may even have several activities going on at any one time, some taking longer than others to complete. For instance, you may have set some seeds to germinate, and exposed some samples of metals to the atmosphere to observe the rate at which they rust, at the same time you are studying the evaporation of liquids in different conditions. However, the various sections of the Handbook have been put in a definite sequence, as follows:

Section I gives you the reasons that led to its production, the rationale and philosophy underlying the approach to science education that SEPA advocates, and the way the Handbook is intended to be used.

Section II gives you an idea of what it means to be engaged in science activities. It deals with various activities performed by training college students under the guidance of their tutors. The responsibility for learning is left largely to the student. You will see that by working in this way, you may gain some of the competence of a scientist and science teacher. This is important for your feeling of security and confidence in the classroom.

Section III should be consulted for activities and related readings with which you may wish to begin. The section offers a variety of materials that may lead to truly integrated science activities and situations. It is intended to get you involved in investigations of your own - the first step towards developing competence, confidence in yourself, in your ability, and in the validity of your own ideas.

Section IV gives illustrations of how this approach has worked and can work with children. It shows that doing science is well within the capabilities of even very young children, and provides you with examples to cite in support of this idea.

Section V explains why you must let children learn science in this way. It provides you with some of the answers you will need to have ready for often well-meaning conservative educators who try to weaken your confidence. They do this by arguing the advantage of speed that the lecture/demonstration method has as opposed to activity-oriented learning.

Section VI describes some of the things you need when you decide to give children the opportunity to learn some real science.

It gives you the "How to do it." The section also deals with the knotty problem of how you assess children's experiences, and how to handle social pressures against discovery learning.

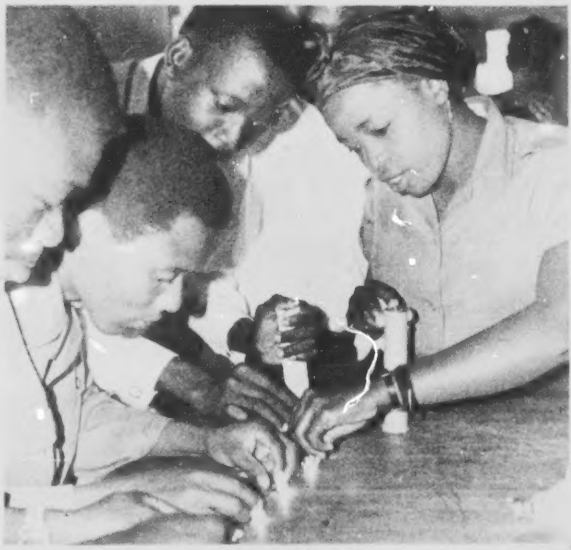
Many teachers seem to feel that children cannot learn very much that is useful if they are given materials and left to work on their own. Reading through this handbook, a teacher cannot help but become aware of examples of work done by children with minimum assistance from teachers. The role of the teacher in assisting children to learn science in this way is given in Sections V and VI of the handbook. For a teacher to appreciate the excitement that children experience in working this way, it is necessary for the teacher to do some of the suggested activities on his or her own.

This handbook is not a conventional textbook, and the ideas presented are not arranged sequentially. This means that in order for the tutor or teacher to maximize the usefulness of the handbook, he must first familiarize himself with what is contained in all the sections.

In guiding students, a teacher is advised to combine the science activities with the pedagogy activities given in Sections V and VI. In essence, there is a need to shift back and forth rather than to go in sequence chapter by chapter. In this way, the spirit of the approach is fully grasped. It gives you the "How to do it." The section also deals with the knotty problem of how you assess children's experiences, and how to handle social pressures against discovery learning.

SECTION II

ILLUSTRATIONS OF STUDENTS DOING SCIENCE



BATTERIES AND BULBS - Tutor Working with Pre-Service Students

ATTRIBUTES - Child and Student Working Together as Tutor Looks On

LIGHT AND MIRRORS - Student on Practice Teaching with Std. V. Boy

A STUDENT'S PROJECT

SECTION II

ILLUSTRATIONS OF STUDENTS DOING SCIENCE

Introduction

Why teach science at all?

The answer to this question requires deep thought, not only about the nature of science itself, but also about the teaching-learning process. Too often the way that science is taught is misleading, be it during the early years of primary school, or at secondary school and Teachers College. The emphasis is placed on rote learning about the discoveries of others, giving the learner a mistaken or distorted view of the nature of science. In the process of learning, a person who may become a primary school leaver often has no opportunity to acquire the problem solving skills which can be helpful in day-to-day life. Nor, if he is to become a primary school teacher, does he gain the skills necessary to provide a suitable environment in which others can acquire these skills.

As one scientist has put it "... the discovery cannot very often be a new one; it is too hard a task to expect the schoolroom to recapitulate the history of science ... (but) Any study of science that does not allow the possibility of discovery is a stultifying one, above all at introductory levels."

The excerpts that follow are examples of work written by students who were given the opportunity to carry out their own science investigation in an atmosphere conducive to free exploration and discovery.

Chapter 1: Investigations With the Ant Lion

Using the activity approach to learning science, the same materials can be used at many different levels. Although the situation may be the same, the question asked by the investigator will depend on his or her experience and stage of intellectual development. What follows is an excerpt from the report of an associateship student attending a one year Diploma Course at the University of Ibadan. She had never studied science.

Investigations With the Ant Lion

by

Mrs. Anderiyike Ayankogbe
Associateship Student, University of Ibadan

Introduction:

The Ant Lion is a common insect larva found in loose dry sand. Yoruba children enjoy playing a game to the song of the ant lion. As the children sing, "Kuloso (ant lion), abiyamo fohin so," they behave like an ant lion by jumping backwards.

The ant lion is of no economic importance to the farmer, hence no detailed study of this insect, and of how to control it, has been done. However, the ant lion is an example of a source material which can be collected on Nigerian soil. Observing it, gives the primary school teacher an insight into various activities that can be suggested, and carried out, by children.

Working with an ant lion can be interesting and exciting, and many scientific ideas and principles can be gained. Such work trains the student to be curious, observant and vigilant when trying to find a solution to a problem. Perseverance, patience, and alertness are necessary for working with the ant lion, plus interest to want to work on one's own after the school hours.

This study was started on October 4, 1968 during class activity under the direction of Dr. E. A. Yoloye, my science tutor. His approach to science study is the open-ended approach and it generated in me the desire to study the ant lion beyond any study undertaken by others in the class, and, finally, perhaps to lead me to some contribution in the study of nature in my immediate environment at the University of Ibadan.

This study was based on observation and experiment with environmental phenomena unknown to the ant lion. At the same time questions were posed to direct the investigations necessary to arrive at conclusions.

Science has taught us the lesson that there is no absolute truth; truth about a thing may change according to the prevailing circumstances. The findings in this study can be taken as reliable to some extent because they were based on actual observations. Classroom discussion with other associateship students gave opportunities for comparing and sharing knowledge in relation to the findings. In studying any phenomenon in science, I have learned that there is not always one correct answer or solution to a problem, or always one method to the finding of a solution. And finally, in an attempt to find an answer to a problem, other discoveries are made which might not have been anticipated. This is an incentive to pursue the new discovery to gain knowledge.

I am very grateful to my science tutor, Dr. Yoloye, for encouraging me to collect my findings and submit them in this form. I hope this paper will lead others to the desire to work with this open-ended approach to science study, an approach used in the African Primary Science Programme Unit, "Ask the Ant Lion."

PART I

In this and subsequent sections, the discussion will, in general follow this order:-

Question asked;
Study carried out;
Findings or discoveries made.

1. Can an ant lion make its funnel trap in materials other than soil and still prey on a victim?

I prepared an observational plate with a heap of gari (cassava fried to look like dry soil) and dropped three ant lions onto the plate at 9:30 p.m. At about 9:35 p.m. one entered the heap of gari. A moment later, the second also entered the gari and started to make a funnel, but later stopped. The third, which was on its back, flipped to normal position at 9:45 p.m. and stayed on the heap as if pondering something - perhaps a sensation of being on a different environment. However, at 9:51 p.m. it made an inward, backward movement and entered the gari at 9:52 p.m., throwing the gari upwards until a small funnel was formed. These observations show that this environment is conducive to the ant lion's way of life. Findings by other students in my class also revealed that an ant lion can make funnels in dry starch and in cassava powder. This is an adaptation to a new environment. In our experiments there was no clear evidence that the ant lion has a preference between gravel and loose dry sand; I think, however that an ant lion would prefer the sand to gravel, since gravel would be heavier for it to throw when making a funnel. Previous observations support this deduction since ant lions were found mostly in loose dry sand.

PART II

2. When any prey is caught, what happens?

The ant lion draws the prey inside the sand and covers it with sand. Later observations showed that the carcass of its prey (an ant) was thrown out of the funnel. This made me deduce that the ant lion does not eat its prey but sucks the juice from its body.

3. Does the ant lion suck from dead insects?

I dropped a dead ant into the funnel to see whether the ant lion would seize it. It did not touch the ant. I repeated this with a small red worm which was dead but the ant lion also threw that out after some time. Perhaps the ant lion does not suck from dead prey.

4. Does the ant lion catch prey on a flat surface?

A study carried out on a table, a plate, a tray, and a piece of paper showed that it did not catch prey on flat surfaces. The prey walked over the ant lion. I repeated the tests, but the ant lion did not touch the prey. I then returned the ant lion to the sand tray to see what it would do with the same prey. When the ant lion was left to make a funnel and I dropped in a red worm, the ant lion seized it immediately. The ant lion preferred its natural abode for catching prey.

5. An experiment to test the lecturer's suggestion that an ant lion eats termite wings and body or other insects in an enclosed perforated tin.

The same ant lion that preyed on the smaller one was removed from the gari and put in a glass tumbler overnight with small moths and two termites. There was no sand in the tumbler which was covered with a piece of netting. In the morning the moths and termites were found dead, as if life had been sucked from them. The ant lion did not eat the body or wings. To prove this further, I left the larva with the dead insects for two days. The dead insects remained as they were. Closer observation did not reveal that the ant lion had a mouth for eating. An ant lion does not eat the wings or bodies of moths and termites. However, it seems as if it can catch its prey on flat surfaces if it is enclosed with the prey so that the latter cannot escape.

PART III

Physical Features and Movement

6. What are the physical features of the ant lion?

Its body is hairy with black spots. It has a segmented abdomen which is of a light brown colour. It is diamond shaped with three pairs of legs; two folded on its abdomen, two (longest ones) outstretched from the chest and two (tiny ones) stretched toward the head. Its body is divided; head, chest/thorax and abdomen. On its head are two curved pincers and on either side of the pincers are two black spots, appearing to be eyes, and two black, outstretched, very slender feelers. Observations of smaller ant lions did not show the feelers and this suggests that the larva matures in stages of development.

PART IV

Reactions of Ant Lions to a Variety of Situations

7. What is the ant lion's reaction to exposure?

Observation showed that ant lions can walk a long distance before finding shelter in the soil. The four ant lions kept under observation in the plate, left the plate on several occasions, dropped down from the high laboratory table, and walked away to dark areas. They were recovered and put back in the plate.

8. What position does the ant lion occupy in the funnel trap?

Some students in my class suggested that the ant lion stayed at the upper part of the funnel while I and others, said that it stayed at the bottom of the funnel trap. To discover the answer, I went on a tour of the compound to observe many traps and found the upper position to be true as well as the bottom position. In my observations, I dug out one in the upper position and found it to be developing into the next (pupa) stage. Another discovery to support the upper position was the cocoon I dug out unknowingly at the top of another funnel.

I concluded that at the beginning of the third stage of development to pupa, no food is needed, so the ant lion moves from the original position to the top of the funnel.

PART V

Research to Determine Different Species of the Ant Lion

9. How many species can be found on the University of Ibadan campus?

I collected 45 from various parts of the campus to learn whether differences in environment would determine the species, or whether those same differences would influence body colour.

The collection ranged in size from tiny to very large. The ant lions were scooped into an enamel cup and taken to the science laboratory where they were spread out on a flat plywood surface about two feet square. I observed the ant lions one by one with the hand lens.

Findings:

Only one looked different from the others. It looked more hairy and its body was longer and thinner than those of its same size. I called the laboratory assistant's attention to this. He suggested that the different one might be a male, but I dismissed that idea because there would be more than one male in a collection of 45 specimens.

Conclusions:

Only two species of ant lions are found on the University of Ibadan campus.

10. Is there other evidence to support two species?

The first evidence was shown in the sizes of the cocoons brought to class. The cocoons formed by the ant lions I had reared were smaller than those brought by another student.

Cocoons also vary in build. Every part of the cocoon brought by another student was covered with sand, while only part of my cocoon was covered. The bottom of the cocoon revealed a whitish looking cellophane-like membrane out of which I presumed the adult would crawl.

11. How does the inside of the cocoon look?

On opening one, I found black and grey carcass of the ant lion, and looking into the cocoon itself, I was amazed by the beauty of the silvery silk home the ant lion had built.

From another cocoon I pulled a carcass which was white and different from the first. This was more evidence to support my idea of two species to be found on the campus.

12. Is there evidence from other sources to support the number of species?

To answer this question I went to the University Library to find more information about the ant lion. From the Encyclopaedia Britannica I found that mnay species have been discovered in many parts of the world (65 species have been identified in the United States alone).

To find out how many species have been identified in Nigeria, I went to the Entomological Department of the Faculty of Agriculture. I was shown five species already identified and arranged in boxes for study. The five found in parts of Nigeria were classified as follows:

Order - Neuroptera
Family - Myremeliontidae
Species - Marcelon validis (ant lion)
(a) palparis, furfureua) Rambur have yellowish
(b) palparis tigris dalm) patches
(c) stenares hyeenay dalm (greyish)
(d) tomatares clavicornis latr
(e) Mclachlen (specie found at Ibadan)

PART VI

The Adult Ant Lion, Sex and Its Food for Survival

13. What can be done to keep the ant lion in its adult stage alive for more than three days?

Various experiments with rearing had failed to keep an adult alive. On my second visit to the Entomological Department, it was suggested that I prepare sucrose in a specimen tube, using cotton wool as the lid of the tube so that the adult ant lion might suck the sucrose from the cotton wool.

The next ant lion that emerged from its cocoon failed to settle on the cotton wool soaked in sucrose. It did not satisfy its need for food and it died on the third day.

Hope came to me when, on 10 April, I discovered from F.S. Taylor's book, Science Past and Present (page 63) a story that suggests that the ant lion does not take food. The imaginative story goes:

> "And this animal when born, swiftly perishes because it cannot avail itself of food and so dies of hunger. For being of two appetites, when he wishes to take meat, the nature of the ant has an appetite for seed, and refuses meat. But when he wishes to be nourished on seeds, the nature of the lion resists him. So being unable to eat either meat or seed, he perishes."

I then decided to try to feed an adult ant lion on water, since many insects feed on sweet things such as nectar.

I fed the next adult ant lion that hatched in the following way: (Pupation of the adult was from 18 March to 11 April).

Date	Time of Feeding	Tool Used	Food Given	Quantity
April				
11-15	Did not feed on the cotton wool		sugar water	
16	3.00 p.m.	Tip of knife	Sugar water	Minute amount
18	2.30 p.m.	Tip of knife	Glucose	Refused
20	3.00 p.m.	Tip of knife	Sugar water	Minute amount
26	3.15 p.m.	Made it drink from container	Sugar water	Comparable with previous occasions
May 2	7.15 a.m.	From a teaspoon	Sugar water	Negligible, adult looked rather disturbed and flapped its abdomen.

On 6 May I was sorry to see that the ant lion adult I had been studying was trapped by a spider's web and was hanging in space in the rearing cage. Though the spider curtailed the life span of my ant lion, I had been successful at keeping an adult ant lion alive for three whole weeks, an achievement which has not been recorded in any book I have so far read.

PART VII

Though this is the end of this paper, I have not finished my assignment on the ant lion and its ways. I started to rear others that would lead me to keep both males and females so that I could study the process of reproduction to see what the eggs of ant lions are like. It is a pity, however, that much as I would have liked to continue with such a research, my role as a housewife will not allow it. I have left the campus for home and the care of children and husband. However, I shall keep my assignment in mind and hope I can make a contribution to life's knowledge by further investigation of the ant lion's ways.

This represents only a portion of Mrs. Ayankogbe's report. Some of the many other questions she investigated were:

Do ant lions prey on one another?
How long does it take an ant lion to kill a prey?
How does the ant lion move?
Are ant lions found in wet funnels?
How long does it take a larvae to change into the pupa stage?
What does the adult ant lion feed upon?

To conclude, we quote from the comments of Professor E. A. Yoloye who, as stated in the excerpt, was the supervisor on this project:

> Many educators would agree that if a teacher is to generate excitement in a particular way of learning in his student, he should himself first experience such excitement. It has not always been clear however if the same units prepared for children could form the basis of the curriculum for the teacher. The paper presented by Mrs. Ayankogbe summarizing her own investigation is a striking example of how a mature adult teacher could get hooked on the same unit that was written for children and carry out meaningful and challenging investigations.
>
> Science educators may find the paper a useful additional tool for teacher training. There are several conclusions in it which other teachers may want to challenge. There are a number of unanswered questions which other teachers may want to pursue.
>
> I should mention that Mrs. Ayankogbe had practically no science instruction before coming on the course. This should be an encouragement to teachers who fear that their lack of training in science may be a great handicap in learning to be a science teacher.

Chapter 2: Solar Eclipse

This report of observations of the Solar Eclipse in 1973 by a class in a Teacher Training College in Kenya was written by a second year student. The class had done science at secondary school before entering college.

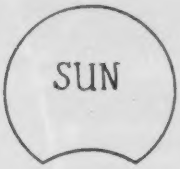
SOLAR ECLIPSE 30.6.1973

As observed by members of Pl 2C
and condensed by Calestous Juma

OVSERVATION 1 (THE SUN)

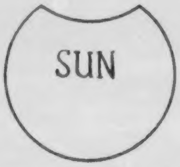
2:45 p.m.: This was the time when the first contact occurred. This was clearly seen by means of Exposed Negatives and Pinhole Cameras. Clouds partially covered the sky thus allowing some people to use naked eyes. According to those using negatives, the first contact appeared as shown below.

A.



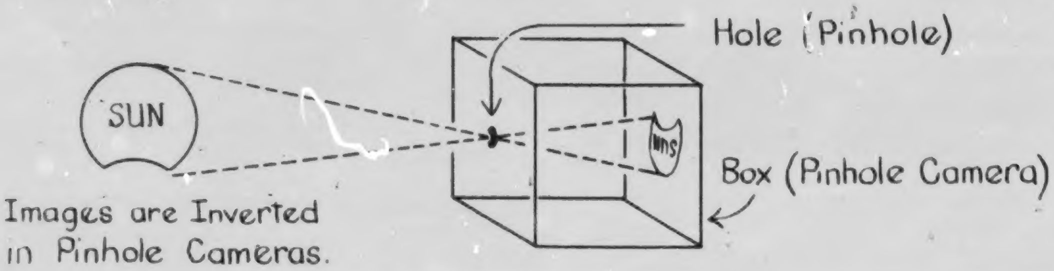
Using Negative(s)

B.



Using Pinhole Camera

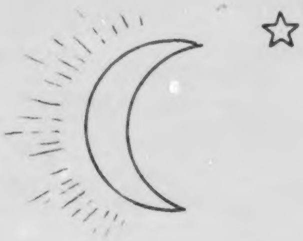
In "B" above, the missing part is where it is because of the explanation given in the figure on the following page.


Hole (Pinhole)
SUN
Box (Pinhole Camera)
Images are Inverted in Pinhole Cameras.

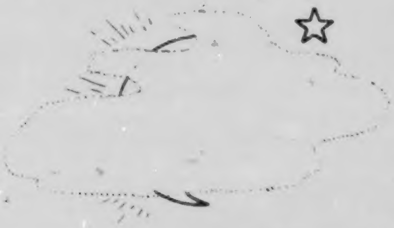
The following is from film negative observation.

3:05 p.m.: About 1/8 of the sun was missing and a big cloud came and covered the sun thus allowing people to use naked eyes.

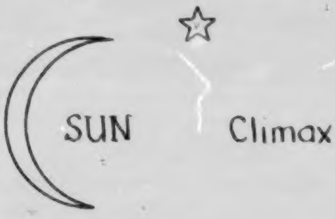
3:15 p.m.: There appeared a big beautiful star near the sun and there was a great difference between the light in the north and that to the south. This time there was a sparkling light from the sun. It looked like this:



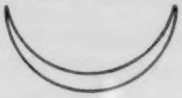
3:30 p.m.: At this time the light from the sun looked more yellow than colourless. Within a few minutes, the sun was invaded by a pink-like matter; irregular in shape, and before a further observation could be made, a big cloud covered everything. The scene was this way:



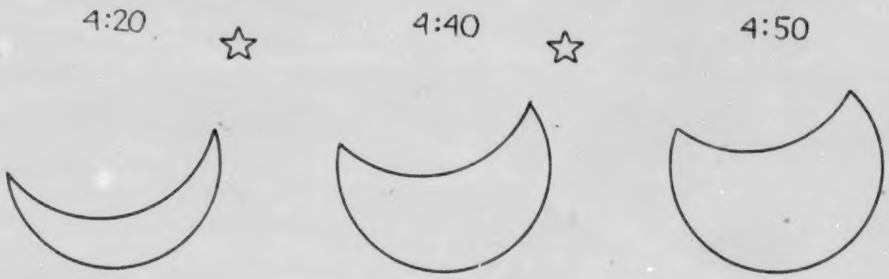
4:00 p.m.: There remained a small part which gave a little light but the north was very dark with a few distant stars visible near the horizon.



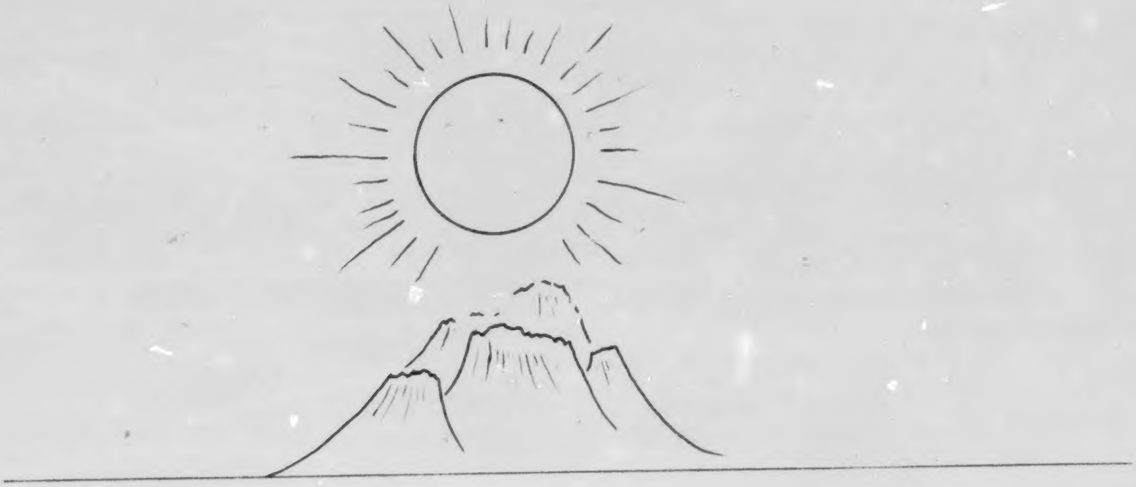
From
4:00 p.m.: There was constant amount of light for 5 minutes when the crescent-like sun was now drifting downwards which suggests that 4:00 p.m. was the Climax of the Eclipse in Egoji (Centre of Observation). I would call this time "State of Stability" because there was practically no increase or decrease of light.



4:10 p.m.: The light increased gradually so the shapes changed as shown here and the glittering star disappeared.



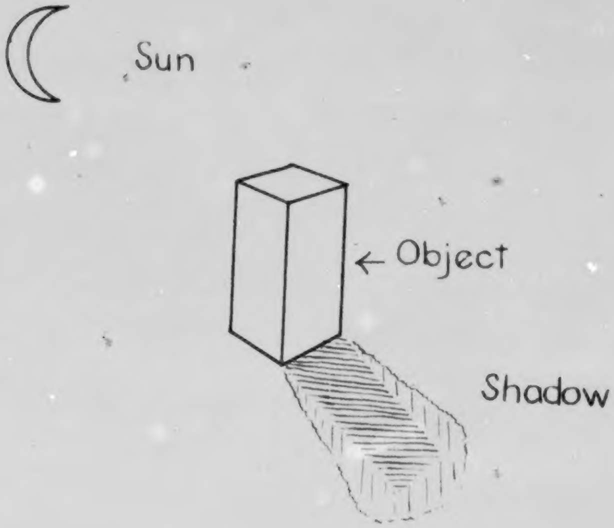
5:10 p.m.: And finally at 5:10 the Solar Eclipse became history or current affairs because the sun was like this:



WEATHER

From the first contact there were many clouds and heavy wind but as light continued to fade away, the wind cooled slowly in comparison with the fading of light. The light was yellowish and clouds had different colours. To the north clouds were darker than to the south. The temperature dropped and it looked like the atmosphere at 6:30 a.m. after a short but torrential rain. People's skins looked as if they flashed with artificial light from a neon lamp.

The shadows were not regular, i.e. they looked like shadows formed by two faint lights.



The speed of the wind was 0 km. per second at 4:10 as observed from the college anemometer.

OBSERVATION 2 (THE EARTH)

Collected from Various Places and Condensed into Facts

FIRST CONTACT

This was not observed by people who had no apparatus to use such as film negatives and pinhole cameras.

As the light faded away slowly, people became more aware and saw the following events opening up:

BEHAVIOUR OF ANIMALS

An observation on birds showed that

a) Birds were flying to their nests and producing what we have decided to call "Evening Songs" or "Prep for Nests Songs."

b) Hens which were also observed in three different places were moving around sleeping places and producing "Open for Me Sounds."

c) Cows were observed in five different places and when what I called "Climax of Eclipse" came, they gathered together in a sense of "Let us get sleeping." After the climax, these animals got scattered again and behaved as if it was in the morning, i.e. shaking the muscles and licking the grass as if there were dew on. In another Observation Centre, cows gathered near the gate to their shed and produced a howling noise as if it was "Please open for us" but before long they found it as in the morning. When light came more, birds again gave different sounds similar to those sounds heard in the morning about 6:00 a.m. or so. Cocks were crowing.

BEHAVIOUR OF PEOPLE FROM DIFFERENT OBSERVATION CENTRES

Children

From different observation centres, children fell under various observatory conditions.

a) Some children were shouting, delighted and made fun of everything as they drove cows home. Some children in a Shamba were called home by their parents and they went to stay in their houses (locked).

b) Some children ran home crying after having been told that this was doomsday.

Women

Women fall in two categories, the old and historical, and the young. The old women said this was natural and it had no effect on eyes because they had seen it during their youth and therefore continued to gaze with naked eyes whenever there was a cloud. The young women were running with their children and putting them in houses while they came out to glance and go back in. In a market some women were packing up their things to go home.

Men

Men were observed from different angles. From a bar, there was a group of drunkards who observed with naked eyes. Many men were using film negatives to observe. A mad man was observed and he had a film negative in his pocket (he was informed) when he saw the light fading away, he said, "Now I'll go to sleep and wait for the dawn," but when he saw people observing through negatives, he took out his and instead of looking at the sun, he looked at the earth and when he was directed to look to the west, he saw the crescent shape and he started shouting in a manner which could be better described by a psychiatry specialist. A man looking after cows was observed. When it became dark (climax) the cows gathered together and he was excited and ran home leaving the obstinate cows. A few men were scared to observe because of the propaganda against it and fear of blindness, and so were their families.

OBSERVORS

Some of the "never-mind-anything" observors had eye complaints as a result of straining through the negatives which could not regulate the light because the power of light was changing from time-to-time. In some the pain continued up to the night, maybe it came because of psychological worry that they would be blinded if they looked, who knows?

GENERAL COMMENTS

Those who used Pinhole cameras may disagree with me because this observation is based on Film Negatives and therefore whatever is drawn here, especially the changing shapes of the sun would appear exactly the opposite of what is recorded because "A Pinhole Camera inverts the image," which is an elementary school fact and there is no argument about it.

What is recorded here is based on the Observation made by members of Pl 2C and not theory from Pl 2C.

The observation was done from different points within a radius of 15 miles although there are identical events which confirm our observations. Some Pinhole Cameras proved useless and none of the observors was in collaboration with any Radio Broadcast, and so everything is purely original.

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The next two reports were written by second year students in Training Colleges. All students had spent two years previously at secondary school where their studies included science. The class had been given a variety of areas for investigation. The reports indicate the areas within which the students chose to work.

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Chapter 3: A Draft of a Teaching Unit Written by a Training College Student

This report was written at a workshop where University Lecturers, Training College Lecturers, Inspectors, Teacher Training College Students and school children worked together to try to find some answers to the pressing problems of science education. At this workshop, participants were not present in their capacities of TEACHERS or STUDENTS. Everyone worked together on an equal footing.

The report was written by a second year Training College student who chose to work with the APSP/SEPA unit Pendulums and himself investigated the behaviour of pendulums. In the course of the workshop he also worked with small groups of children to find out more about how they thought about pendulums. His findings are written up in the form of a teaching unit to help himself and his colleagues work better with children in the classroom.

A Draft of a Teaching Unit

by

S.A. Ray-Palmer

Bo Teachers' College, Sierra Leone

Introduction:

The unit, Pendulums, is written particularly for the teacher. It does not intend to tell the teacher how to go about teaching the children about pendulums. I expect he will wholeheartedly allow the pendulum to do this.

This pamphlet aims at helping the teacher to involve his class of children in the study of the movement of pendulums. By doing, watching, and thinking through these processes, they will come to discover answers to the many problems they will encounter during the course of their explorations.

There are many, many ways of studying pendulums and there are problems of many kinds. Problems of the type of apparatus and materials that will be appropriate, problems of areas of study, problems of getting the needed accurate results which at the end will determine your conclusions. The children and their teacher will do the asking, and the pendulum will do the answering. Although this pamphlet raises some questions for initial explorations, there are many other questions that could be asked for further study of pendulums. The teacher should realise that the questions asked by the children are far more important in the field of learning. They clearly give a picture of the children's interests and the direction in which the teacher should guide them.

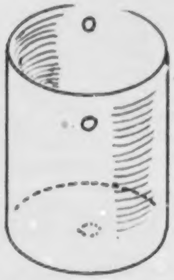
Not all children are interested in all the questions that are asked in this pamphlet. Some of the activities described may appeal to a certain group of children, but not to all the children in the class. Never force the children to follow the pamphlet. Allow the pendulums to set the patterns for their investigations.

I feel that the unit, Pendulums, is intended primarily for children in Middle and Upper Primary classes, but some of the activities could also be used with children in the lower classes of your choice.

HAVE YOU EVER TRIED TO FIND OUT FOR YOURSELF THE POINT AT WHICH THAT MYSTERY PENDULUM MOVES FASTER?

EXPLORATION A

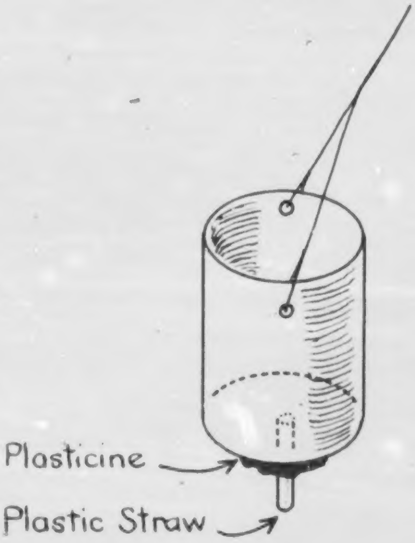
Materials: String about 12 feet long; an empty tin; nails; a hammer; a piece of chalk; ruler; plasticine; water; plastic or paper drinking straws.



Set-up: Using the hammer and a nail, punch a hole through the bottom of the tin, placing it as much as possible in the centre. Make two other holes up at the sides. Attach a string to the rafter of your room or verandah where you wish to carry out your explorations. At the other end of the string, attach the tin through the two holes in the sides.

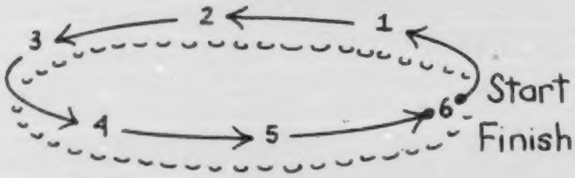
Push a drinking straw through the centre hole, so that one end of the straw is about level with the base of the tin. Cut the straw so that the other end sticks out the bottom of the tin by one inch. Hold it in place with plasticine.

What else do you think the plasticine is doing? Put in water and test. What do you observe? Do you need any adjustment? Why?



Stage 1

Fill the tin with water. If you pull the tin to one side and then let it go, it should swing evenly from side to side. Mark the positions of the drops on the floor. Make it swing once in a circular path and catch it just as it completes the circle (see diagram on the next page).



Count the drops in tens (say) and measure the distances between the drops using the string and the ruler. What are your various measurements? Repeat the experiment three or four more times. Compare the measurements. What conclusion can you make?

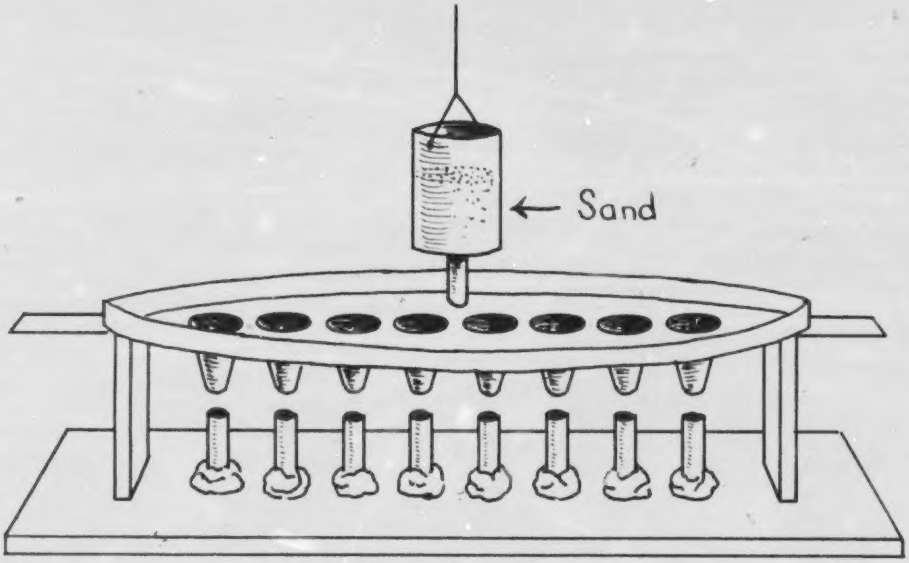
Stage II

This time let the tin move along a straight path dropping the water as it swings along. Catch it at the completion of one swing. Using the piece of chalk, quickly mark spots of the drops of water, and measure in tens (say). Why do you think it is good to mark the spots? You need to do this three or four more times, and compare the various measurements. What patterns are the measurements making? Do they show any sign of a relationship? What other observations have you made?

EXPLORATION B

Materials: Drinking straws; sand (dry); a strong paper sheet(vanguard); three pieces of wood, one with the measurements of about 10" x 4" x 1/2" and two of about 6" x 3 1/2" x 1"' small funnels; plasticine.

Make your apparatus as shown in the diagram on the next page. A tray, made of the strong paper, can be used to hold a row of small funnels over the row of straws. Use the plasticine to hold the straws firmly in their places. Put a quantity of sand into the pendulum tin.

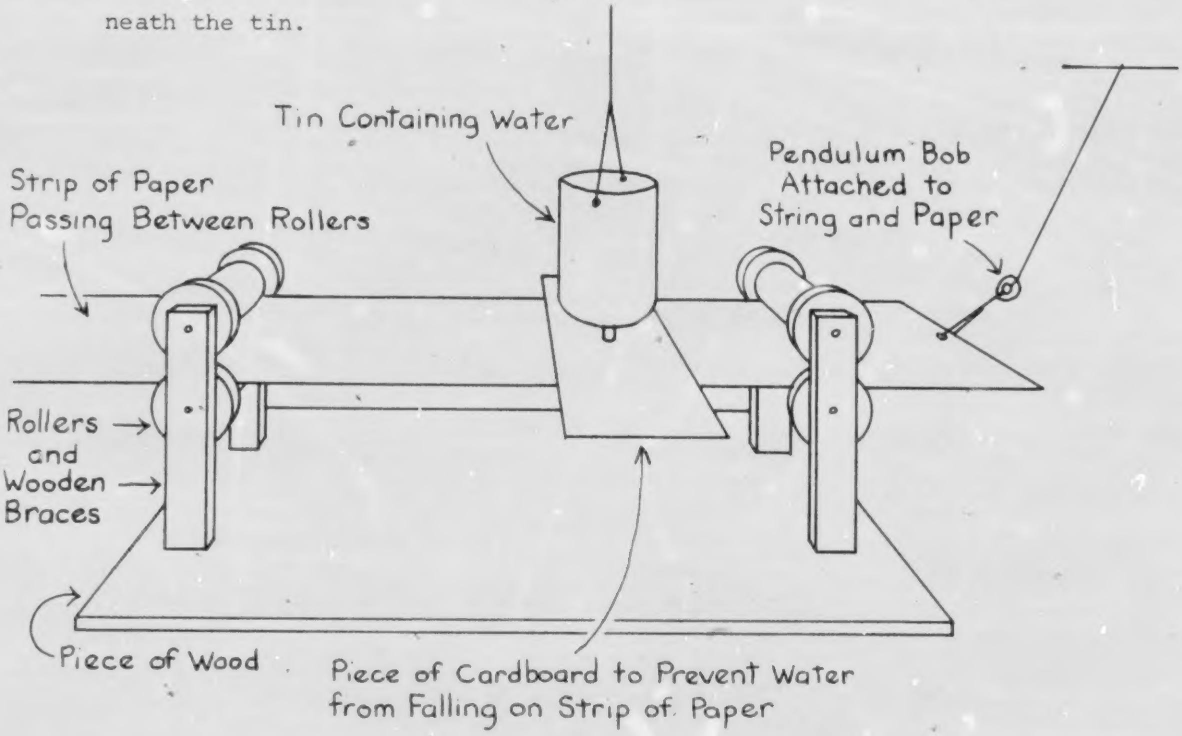


Put the pendulum tin to one side and let it go. You must make sure that the hole in the tin serving as an outlet moves directly over the opening of the funnels which lead the sand into the drinking straws. Let the pendulum swing a number of times (six to ten times, say), dropping sand into the drinking straws through the small funnels. Measure the sand deposited into the straws using a graduated cylinder. You can do this three or four more times. Each time, make recordings. Later compare the various measurements. What patterns do your readings make? How can you explain what you observe?

EXPLORATION C

Materials: The pendulum used in Exploration A; an extra pendulum bob; a strip of strong paper (vanguard) joined end to end to make a continuous strip about two yards long and three inches wide; four rollers (cotton reels, large size); nails; pieces of wood; and a hammer.

Construct your apparatus as shown in the diagram on the following page. The paper strip on which the water drops will be recorded should move freely between the two sets of rollers. Avoid water inside the tin from dripping on the paper by holding a piece of cardboard underneath the tin.

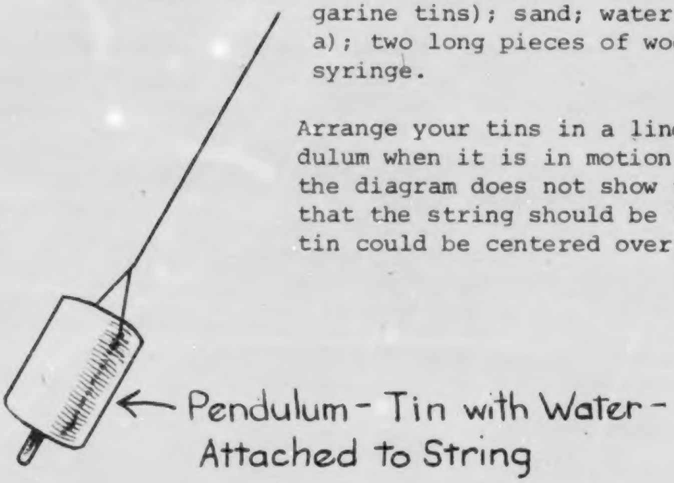

Tin Containing Water
Strip of Paper Passing Between Rollers
Pendulum Bob Attached to String and Paper
Rollers and Wooden Braces
Piece of Wood
Piece of Cardboard to Prevent Water from Falling on Strip of Paper

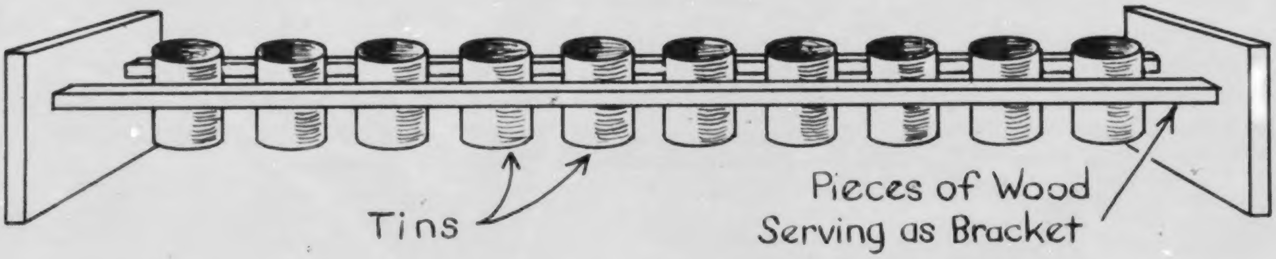
Ask your partner to hold the pendulum bob, and watch for you to remove the piece of cardboard as a signal for him to release the pendulum bob. Quickly mark the water-drop spots made as the pendulum bob pulls the paper strip underneath the water dropping from the tin. Then measure the distances made between each drop. What patterns have the drops of water made? What do your readings tell you about the motion of the pendulum? Repeat this three of four more times. Compare the different measurements. Make a graph of your measurements. What can you say about the graphs? Why have you used double rollers instead of single rollers? Why should you use the rollers?

EXPLORATION D

Materials: Several containers of the same size (try Blue Brand margarine tins); sand; water; pendulum (used in Exploration a); two long pieces of wood about 2" x 4" x 10"; a syringe.

Arrange your tins in a line following the path of the pendulum when it is in motion. See apparatus below. (Though the diagram does not show the length of the string, you know that the string should be long enough so that the pendulum tin could be centered over the apparatus.)


Pendulum - Tin with Water - Attached to String



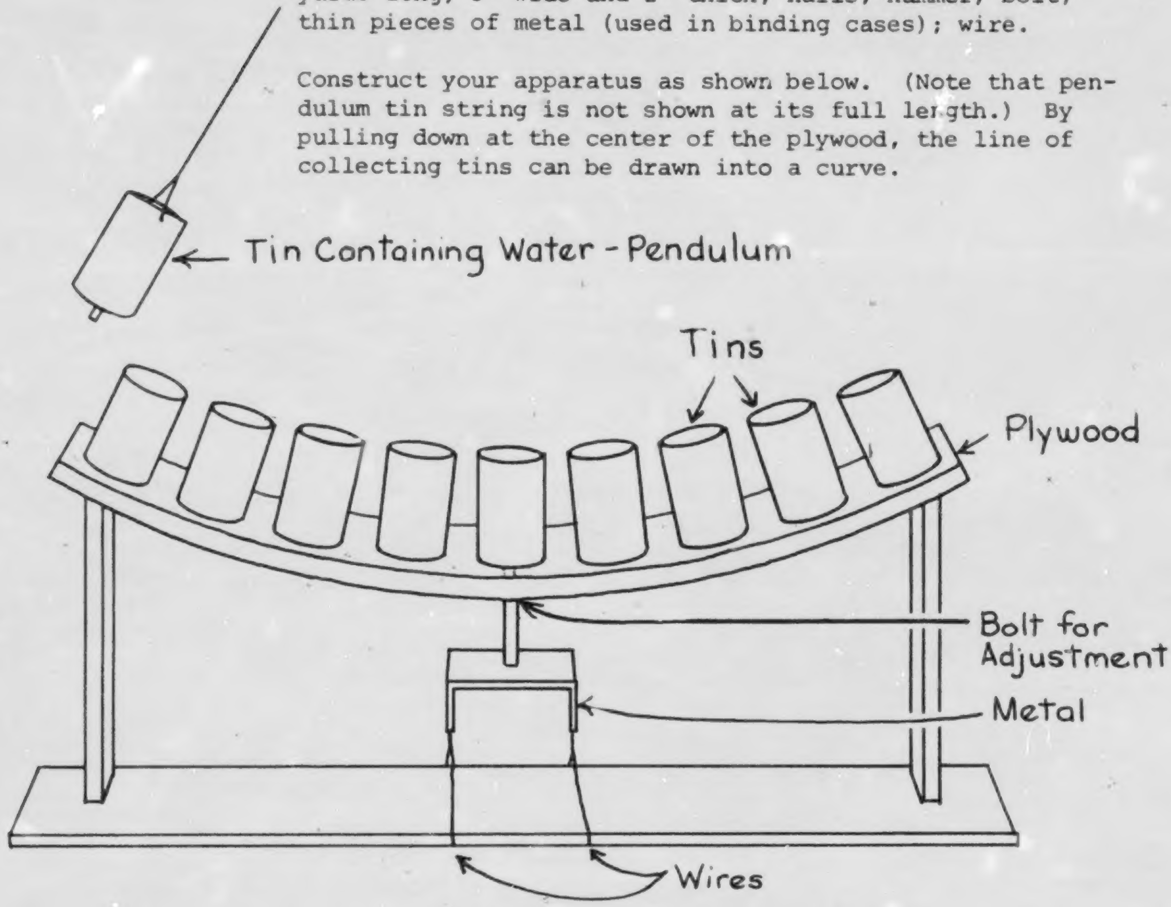
Let your pendulum swing over the tin for about ten minutes. Use the syringe to measure water deposited in each of the tins. What are your measurements? Repeat this three or four more times and record the measurements each time.

How do your measurements compare with one another? Make a graph of your measurements and see what pattern they make. Now use sand instead of water. Measure and compare. Is there any difference. If so, what is the cause? Can you think of any way to eliminate this difference?

EXPLORATION E

Materials: The same tins and pendulum used in Exploration D: a piece of plywood about two yards long by 4" wide (plywood is recommended because it is flexible); a piece of wood two yards long, 5" wide and 2" thick; nails; hammer; bolt; thin pieces of metal (used in binding cases); wire.

Construct your apparatus as shown below. (Note that pendulum tin string is not shown at its full length.) By pulling down at the center of the plywood, the line of collecting tins can be drawn into a curve.



Pull the tin to one side and then let it go. It should swing evenly side to side over the tins, dropping water in each tin as it swings. Allow it to swing four, five, or seven more times. Measure the water collected in each tin. What pattern are they making? What is your observation? How do the results compare with those from Exploration D? What explanation can you offer for any differences you observe?

Chapter 4: Stretching of a Rubber Band

The investigation described below was carried out by Mr. J. Njeru and Mr. I. Ibrahim, two second year students at a Teachers College in Kenya. The topic was chosen from several possible topics offered for investigation by their tutor.

The study was not finished, but rather left these students with several questions to investigate after they leave the College. Might this experience not furnish these students with starting points for investigations they can do with their pupils when they become teachers?

It is suggested that the reader examine this work carefully. How could the work of these students be improved? Have they obtained the maximum information from their data? Are their conclusions logical and complete? The reader may want to repeat some of the experiments described below in order to answer these questions to his or her own satisfaction.

THE STRETCHING OF A RUBBER BAND

by Joseck J. Njeru
and Joseph I. Ibrahim

Problems: We all know rubber bands and how we use them in our daily life. But have you ever sat down to think deeply about them? There are so many interesting problems dealing with rubber bands. We have dealt with only a few of them. Some of the investigations we wished to carry out are as follows.

1. What is the effect of a load when it is hung on a rubber band? Suppose more weight is added, what will happen to the rubber

band?

2. Do rubber bands of different sizes hold the same weight?
3. After the rubber band stretches due to the weight of the load, will it resume its original length after the load is removed?
4. What other factors might affect the rubber band while holding a constant weight?
5. If a rubber band breaks when it is loaded with 43 cups of water, what will happen if it is loaded with 42 cups and left for a day?

A number of experiments which were carried out to investigate these problems are described below.

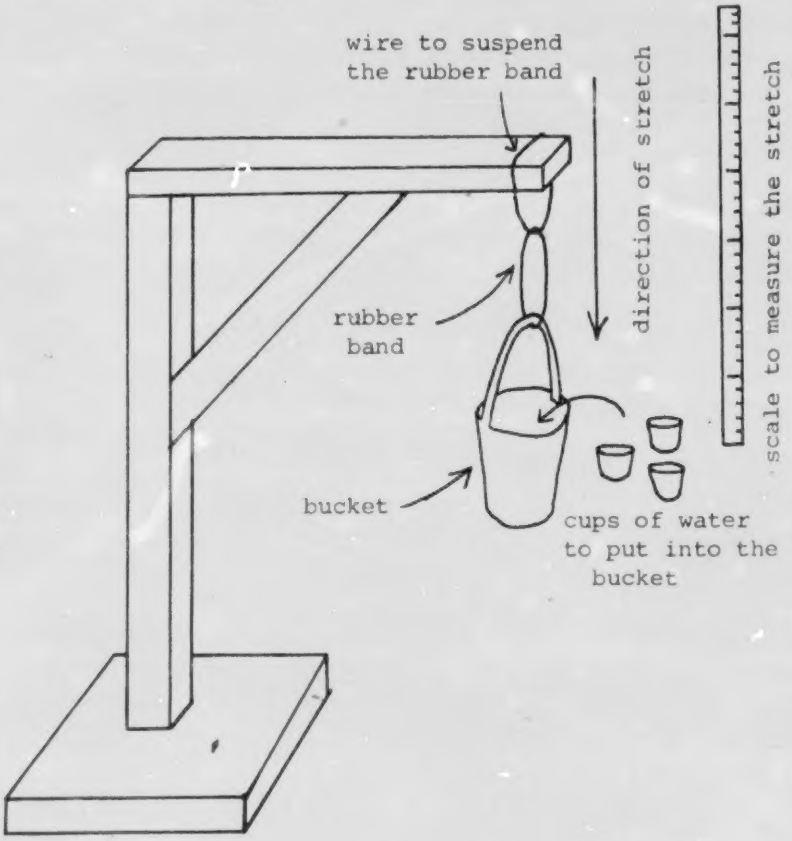

wire to suspend
the rubber band
direction of stretch
scale to measure the stretch
rubber
band
bucket
cups of water
to put into the
bucket

Figure 1. Apparatus used to measure the stretching of a rubber band

Apparatus: rubber bands, ruler, wire, paper cups, bucket, strong nails, water and graph paper.

These materials were used for all the investigations. The methods used for each experiment were different because the problems investigated were not the same. Therefore, we shall take each problem at a time.

Problem 1. What is the effect of a load on a rubber band if it is increased continuously?

Method: Three different rubber bands were used. An empty bucket was hung at the end of the rubber band by tying it with a wire. The rubber band hangs from a wire looped over a board, or could hang from a nail on the branch of a tree.

We measured the length of the rubber band when the bucket was empty. We then continued to pour cups of water into the bucket. Each time a cup was added we measured and recorded the length of the rubber band. This was continued until the rubber bands broke. Then lastly we drew the graphs of the results from three rubber bands and compared their curves.

Results: The tables and graphs are shown on the following pages.

From these tables one can see that each rubber band required a different load to break it. As one increases the weight, the rubber bands stretch further until they break carrying the maximum load.

Rubber band	Unstretched length (cm)	Width (cm)	Thickness (cm)
No. 1	4.0	0.7	0.1
No. 2	8.0	1.2	0.1
No. 3	9.0	0.3	0.1

Table 1. Dimensions of three rubber bands tested*

Problem 2. What is the relationship between the breaking load and the cross-section of the rubber band?

We tried to answer the above problem in the following way. Five different rubber bands had cross-sections and breaking loads as shown in Table 3. Looking at the data collected, we draw the conclusion that the smaller the cross-section, the smaller the breaking load.

Rubber band	Thickness (cm)	x	Width (cm)	=	Cross-section (cm^2)	Breaking load (cups of water)
No. 1	0.1	x	0.7		0.07	44
No. 2	0.1	x	1.2		0.12	45
No. 3	0.1	x	0.3		0.03	28
No. 4	0.1	x	0.6		0.06	34
No. 5	0.1	x	0.2		0.02	22

Table 3. Cross-sections and breaking loads for five different rubber bands

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*Please note that Table 2 on page 45, and Figure 2 on page 46 are part of Problem 1. These should be referred to before going on to Problem 2.

Rubber band No.1.

Load (No. of cups)	Length (cm.)
0	5.8
1	9.1
2	10.7
3	12.4
4	14.0
5	15.3
6	16.4
7	17.1
8	17.3
9	17.9
10	18.0
11	19.0
12	19.5
13	19.9
14	20.3
15	20.7
16	21.0
17	21.4
18	21.7
19	21.8
20	22.3
21	22.5
22	22.7
23	22.8
24	23.1
25	23.2
26	23.4
27	23.5
28	23.7
29	23.8
30	24.0
31	24.2
32	24.3
33	24.5
34	24.7
35	24.8
36	25.0
37	25.2
38	25.3
39	25.4
40	25.5
41	25.7
42	25.8
43	26.0

breaking load

Rubber band No.2.

Load (No. of cups)	Length (cm.)
0	8.7
1	9.6
2	10.8
3	12.3
4	14.0
5	15.7
6	17.5
7	19.0
8	20.5
9	21.3
10	23.2
11	24.3
12	25.4
13	26.5
14	27.4
15	28.2
16	29.0
17	29.7
18	31.0
19	31.5
20	32.0
21	32.4
22	33.0
23	33.5
24	34.0
25	34.5
26	35.0
27	35.7
28	36.2
29	36.8
30	37.0
31	37.5
32	37.8
33	38.2
34	38.5
35	39.0
36	39.4
37	39.7
38	40.0
39	40.2
40	40.4
41	40.7
42	41.0
43	41.2
44	41.5

breaking load

Rubber band No.3.

Load (No. of cups)	Length (cm.)
0	21.4
1	29.8
2	34.8
3	37.4
4	40.0
5	42.6
6	44.3
7	46.3
8	47.5
9	49.1
10	50.7
11	51.7
12	57.5
13	58.5
14	59.0
15	59.6
16	60.4
17	61.0
18	61.4
19	62.0
20	62.4
21	62.7
22	63.2
23	63.8
24	69.7
25	70.5
26	70.6
27	71.0

breaking load

Table 2. Lengths of rubber bands (cm.) versus the load carried (cups of water in the bucket).

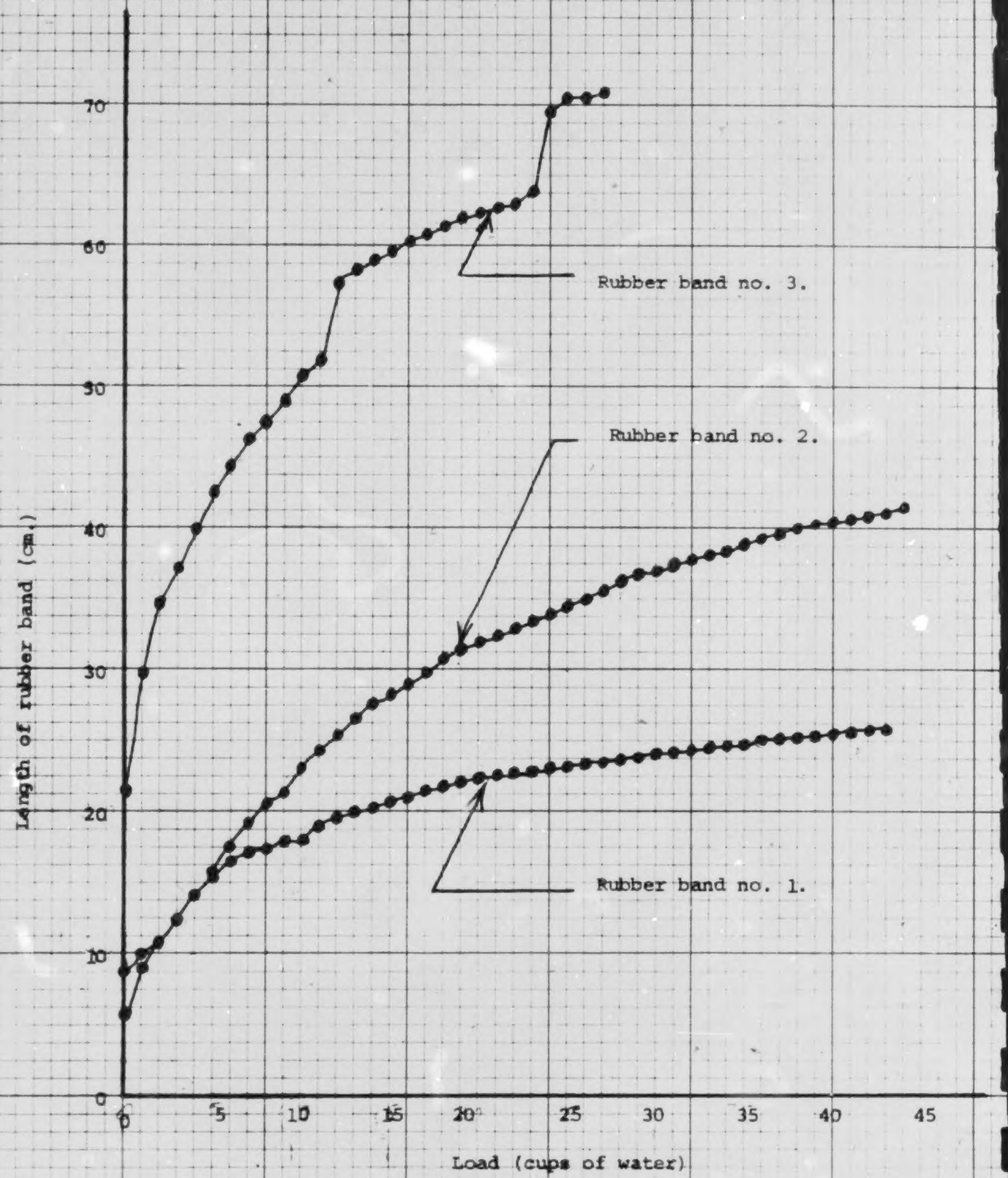


Figure 2. Graphs of the length of rubber bands (cm.) versus the load carried (cups of water in the bucket).

Problem 3. Does the rubber band resume its original size when the load is removed?

An experiment was done to answer the above question. The apparatus was the same as for the previous experiment; a rubber band with a width of 0.3 cm. and length of 9.0 cm. was used.

First the length of the rubber band was measured when 15 cups of water were added to the bucket. Then the load was removed and the length measured again. This was repeated for loads of 20 and 25 cups of water. The results are shown in Table 4. The data show that the rubber band does not resume its original length after holding a heavy load.

Load (cups of water)	Length with load (cm.)	Length with load removed (cm.)
15	59.6	10.0
20	62.4	11.0
25	70.6	11.5

Table 4. Length of rubber band before and after application of different loads.

Problem 4. Other factors which affect the rubber band carrying a constant load.

Method. The rubber band was given a load of 5 cups of water in the bucket and left hanging throughout the day. The length was measured at three different times.

Results:

Time of measurement	Load (cups of water)	Length (cm.)
1st day, 1:30 P.M.	5	42.9
1st day, 6:15 P.M.	5	53.3
2nd day, 7:30 A.M.	5	56.7

Table 5. Stretch of rubber band at different times with constant load

Conclusion: Although we thought the amount of water was constant, the rubber band stretched in a way we never expected. We expected it to remain constant since the amount of water was also constant. Perhaps the environment of our place affected the stretching of the rubber. Possible reasons for the change in length were:

1. change in temperature
2. change in moisture
3. strain of the rubber molecules

Problem 5. What would happen if a load near breaking load is left hanging for a long time?

Method: We found a rubber band which broke when 43 cups of water were added to the bucket. We put a load of 42 cups and left the rubber band hanging overnight.

Results: When we returned in the morning we found that the rubber band had broken. We believe that the possible reasons for this are the same as those mentioned in the previous problem.

This is not the end of the investigations. There are so many other problems on the stretching of rubber bands that one can investigate. So get along and do whatever interests you further on this topic, "Stretching of Rubber Bands."

SECTION II:

Summary

This section has illustrated the approach to science investigations described in Section I. It has shown examples of how teachers in primary schools or students in teachers' colleges can develop an understanding of and familiarity with the scientific approach to solving problems.

It is clear from the examples chosen that even a person who has had little or no formal acquaintance with scientific procedures can soon learn to adopt them effectively. The motivation to adopt these procedures is all important. Such motivation can be developed, or provided, by means of the approach now being considered.

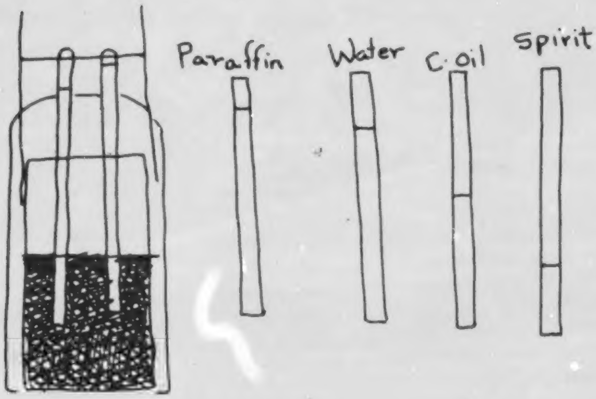
Such studies in science can be challenging to adults as well as to children. Quite often a topic of interest can stimulate investigations from the lower classes of the primary school to the upper reaches of the University. In each case, the learner will be doing science, not just learning about science. This is a difference that should always be uppermost in the minds of science educators.

SECTION III

SCIENCE ACTIVITIES

AND

RELATED READINGS


Paraffin
Water
C.oil
Spirit

No (1) Paraffin is the highest than all
No 2 is water is higher than cooking oil
No 3 is cooking oil is higher than spirit
and the last one is spirit

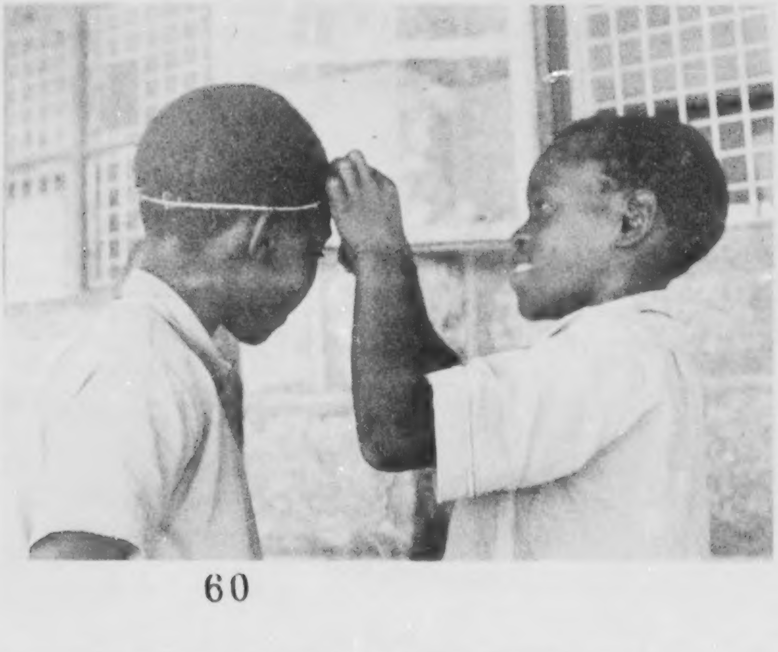
LIQUIDS

CHANGING SYSTEMS

STRENGTH OF MATERIALS

MOTION

"Spinning Things"
Students
Micro-teaching



RELATIONS AND FUNCTIONS

SECTION III

SCIENCE ACTIVITIES AND RELATED READINGS

Introduction

In this section a variety of activities are suggested which are meant to expose the reader to various aspects of the process of carrying out a scientific investigation. The reader is encouraged to carry out as many of the activities as possible not only to read about them, but actively to explore new materials, design experiments, make the necessary measurements, and analyse the results by plotting graphs, establishing relationships, and making predictions that can be verified by further experimentation.

Chapter 1 describes an approach to the exploration of a situation in which there is maximum freedom to explore a variety of ways of investigating a topic; in this instance, Liquids.

Chapter 2 focusses the readers' attention on an area of study which leads naturally to many practical applications. It also can provide the reader with a better understanding of some of the properties of common materials.

Chapter 3 shows how science investigations can be based on the study of a particular scientific concept, in this case the idea of changes and how they are brought about through the exchange of energy.

Chapter 4 treats another scientific concept, that of motion, and shows examples of what can happen when the same concept is studied by persons of different ages and experiences.

Finally, Chapter 5 is addressed to the development and use of an important scientific tool, that of identifying relationships between various kinds of natural phenomena. The reader is encouraged to use techniques such as the graphical presentation of data, to make predictions and build theories which can be verified through further studies.

Chapter 1: Liquids

Introduction

Bricklaying is a human activity. Bricklayers lay bricks; they don't write about laying bricks, or read about laying bricks or listen to people talk about laying bricks. Similarly science is a human activity, it is something people do. In this first chapter of Section III you will be learning some of the more important skills used by scientists; identifying problems, asking questions, and recording, analysing and communicating results. No one will tell you about these skills. You must acquire these skills through working.

AS YOU BEGIN TO WORK ON THIS CHAPTER, READ ONLY AS FAR AS YOU FEEL NECESSARY IN ORDER TO GET STARTED ON YOUR OWN INVESTIGATIONS.

Part I. Identifying A Problem

A. Examine the materials available on your workbench. These could include the following:

1. A variety of sources of colours (or pigments):
    - leaves and flowers of different colours
    - inks of different colours
    - food dyes of different colours
    - felt tipped pens of different colours
    - bic pens of different colours

2. A variety of liquids:

water	
oil	
kerosene	dry cleaning fluid
methylated spirits	lime and other fruit juices
	vinegar, etc.

3. A variety of substances that may or may not dissolve: salt, sugar, starch, napthalene, soap, detergents.

4. Apparatus to help with the investigation of liquids: bottles, jars, tins and other containers of different shapes and sizes. A source of heat.

   (N.B. Not all these materials are necessary. Try to collect a sufficient variety.)

5. You could include other materials that you think would be useful for examining liquids.

B. One of the most important steps in science is identifying a fruitful problem on which to work. To help you to identify a problem to investigate:

1. Write down as many questions as you can about the materials you have collected.

2. Compare your list of questions with those of your colleagues.
3. Write down further questions that may have emerged after discussion of the questions with your colleagues.

   (N.B. During this process pay no attention to whether you think the questions are good or bad. Simply write down as many questions as you can think of.)

4. Classify your questions in a way that you think might be useful. Choose those questions that you think can be answered using the materials available to you.

Part II. Doing An Investigation

Carry out an investigation which will answer one of your questions.

While carrying out this investigation, record your data in such a way that you can prepare a report which will show others clearly what you have done.

Also note the steps you take during the course of the investigation. Other people who read your report should be able to carry out your investigation and arrive at the same result.

Note new questions and problems that come up as you are working. These new questions that arise from your work may form the basis for your next series of investigations.

If you have not yet been able to begin an investigation on your own, doing the following exercise may get you started.

Part III. Examples of How Other Students Solved Their Problems

The following five records were presented by students who have investigated problems posed after an examination of materials similar to those with which you have been working. Study the records carefully.

A. Note whether the investigator:

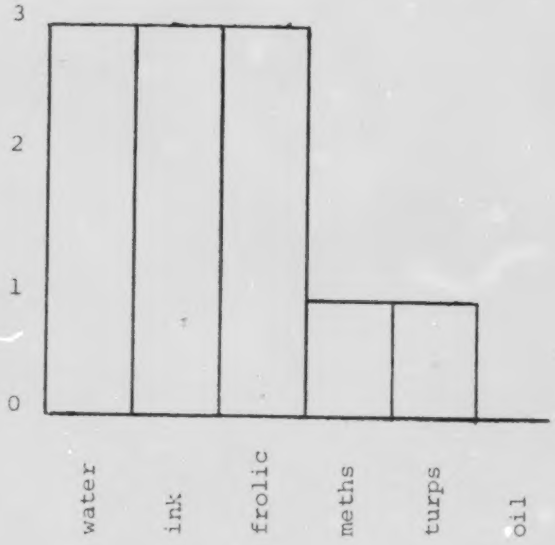
1. Made any errors in the techniques used during his or her investigation.
2. Drew incorrect conclusions. Are the conclusions based on experimental evidence?
3. Noted further questions or problems raised by his or her investigation.
4. Described his or her experiment in sufficient detail for others to repeat it.

B. Choose one of the experiments described in the reports and repeat it to find out if you obtain comparable results.

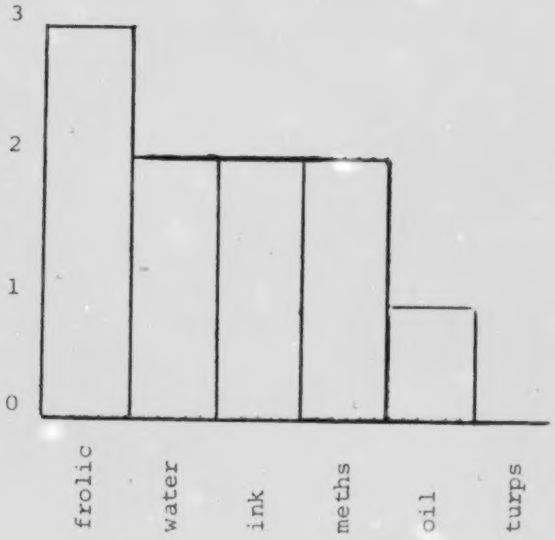
C. Analyse and check your own report and those of your colleagues in a similar way.

Student Record I: DISSOLVING AND MIXING

Frolic soap	Methyl spirit	Turpentine	Oil	Ink	Water
1. Starch	1. Starch	1. Plasticene	1. Frolic	1. Starch	1. Starch
2. Salt	2. Water			2. Salt	2. Sugar
3. Sugar	3. Ink			3. Sugar	3. Sugar
4. Water				4. Water	4. Ink
5. Oil				5. Meths	5. Meths
6. Ink					



Substances dissolved



Substances mixed

Student Record II: STAIN REMOVING

This chart shows the best removers only; the blanks cannot remove.

	Lux	Frolic	Soap	Kerosene	Dryclean	Meths	Turps	Milk	Lemon	Bleach
Grass							Removes a bit			Removes easily
Ink										Removes easily
Fruit					Removes a bit	Removes a bit			Best Remover	
Rust									Removes a bit	
Magic Pen				Best Remover	Removes		Removes			

Student Record III: EXTRACTION OF PIGMENTS FROM PLANTS

Problem:

Do only green leaves make their own food by photosynthesising the material from the ground? Do purple coloured leaves have green in them?

A. Different coloured leaves were rubbed on paper. Drops of different liquids were placed on the marks left. As the liquids spread, colours were noticed. Tomato juice, lemon juice, oil and detergent were the liquids used. No result was observed with oil. Detergent destroyed all colours. Greenish circles were observed using tomato and lemon juice.

Question: Maybe this greenish colour is from tomato and lemon and not from the leaves?

Answer: Trying the juices alone, no green was shown.

B. Purple leaves were rubbed on strips of blotting paper and left to stand overnight in different liquids. Liquids used were water, turpentine, methylated spirits and dry cleaning fluid. The last three liquids gave a quick result but water spread out the colours more. All experiments showed green separating out. Many different leaves were tried with the same result.

Therefore purple coloured leaves have green. Q.E.D.

C. Do flowers contain hidden colours.

Student Record IV: HOW TO MAKE AN INDICATOR

Procedure:

Step 1. Take Hibiscus flowers and crush them in such a way that there won't be any whole leaves left.

Step 2. Add a few drops of water to crushed petals. Put a little water into a tin, insert your petal container and heat gently.

Step 3. Remove the tin and by using a clean piece of cloth or cotton wool filter the substance.

Step 4. Get some blotting paper strips and dip them into the filtered liquid and dry them.

Conclusion:

Test the strips of paper with soap, vinegar, $Ca(OH)_2$ or lime water, lemon, lichen, observe what happens.

Tests with Indicator

Lemon	Lime Water	Tomato	Soda	Vinegar	Soap
Orange	Blue	Orange	Blue	Orange	Blue

Student Record V: CHROMATOGRAPHY

Colour placed on blotting paper strip	Solvent paper is standing in	Result
1. Black Ink	M/Spirit	Purple colour
2. Green Ink	"	Dark brown
3. Brown Ink	"	Purple and light red
4. Black ink	CCl_4	No change
5. Green Ink	"	Light blue
6. Brown Ink	"	Light red
7. Blue Ink	Turpentine	No change
8. Apple green)	M/Spirit	Yellow, green, purple
9. Yellow) food dyes	"	No change
10. Apple green)	Water	Light blue with yellow rim
11. Red Ink	"	All the red carried to the rim
12. Red biro	M/Spirit	Red ring and a bit of yellow
13. Blue biro	"	Purple from meths
14. Blue felt pen	Water	Faint blue
15. Red Ink	"	Faint red
16. Red biro	"	No change
17. Green, black, red	M/Spirit, water	very little seen
18. Brown, yellow, blue	" "	very little seen

Part IV. Problems Raised by Other Students

Below is a list of some of the questions other students have raised. These questions are intended to be useful if you have not found your own project to work on. If you are working on your own investigation, think about these questions. Perhaps later when you have completed your own work you could return again to this list.

If you have not found your own problem to investigate, choose a question and perform investigations that could lead to an answer. Again make a note of the steps you take in answering the question.

1. Do purple leaves have green?
2. What substances dissolve in water and what substances do not?
3. What different coloured paints can be made from plant materials?
4. Can we make our own dyes?
5. Do substances dissolve differently in different liquids?
6. Can I make my own indicator paper?
7. How can stains be removed?
8. What happens when different liquids are mixed together?

Part V. More Student Records

As in Part III, carefully study these reports (and those of your colleagues) and note any comments, criticisms and questions that you have of their techniques or conclusion.

Student Record 6

Problem

Blue always comes to the top of a strip of blotting paper standing in water. Why?

My theories to explain this are:

1. Blue is the least heavy liquid.
2. There is more blue in the mixture of colour.
3. Blue dissolves easier.

The experiments I did showed that my last theory is correct.

Student Record 7: HIBISCUS INDICATOR*

The experiment described below is the result of working with flowers and some common substances. While working with flowers and common substances, it was discovered that certain substances such as vinegar, lemon juice, lime juice, etc., turned the violet colour of hibiscus on paper to a pink colour, while others such as wood ash, banana ash, paper ash, bicarbonate, etc., turned the violet colour to a greenish one. The problem which led to the experiment below was how can you determine the relative strength of the two groups, those that turn hibiscus colour pink and those that turn it greenish.

---

* Investigation carried out by a participant at a 6-month SEPA course held in Ghana, April to October, 1972.

The method used was to measure (by counting the number drops) the amount of a member of each group that was needed to completely cancel the effect of a member in the opposite group which was used as the standard. One can tell the point at which this happens only by using something that can change colour and so hibiscus solution was used as the indicator. With a careful reading of the procedures and results, you will get a better understanding of this paragraph.

To estimate the relative strength of the members in the bicarbonate group (those which turn the violet colour to a greenish one), vinegar was used as the standard. Two drops of vinegar, two drops of the indicator (hibiscus solution) were added to produce a pink solution. Bicarbonate solution was added drop by drop to the mixture - counting the drops and noting the colour of the mixture after each drop. It was found that after the second drop the pink colour vanished which showed that the vinegar effect had been cancelled. The addition of the third drop made the whole mixture greenish which showed that the effect of the bicarbonate was stronger in the solution.

Using the above procedure, several members in the bicarbonate group were tried. Wood ash was tried and it was found that five drops of the solution were needed to cancel out the effect of two drops of vinegar. Therefore, the bicarbonate must be stronger than the wood ash. Banana ash was also tried and it was found that 25 drops were needed to cancel the effect of two drops of vinegar. Therefore, the wood ash is stronger than the banana ash.

To determine the relative strength of the members in the vinegar group, we used the same procedure using any one member in the opposite group (bicarbonate group) as the standard.

N.B. 1. The various ash solutions must be filtered so that you can better determine the colour changes.

2. The standard must have a definite volume and concentration.

Student Record 8: TO TEST THE SENSITIVITY OF AN INDICATOR

(Investigation carried out by a teacher attending an in-service course in Nairobi, December 1973).

Procedure:
1. Put one drop of vinegar in a test tube.
2. Add and count drops of water to the vinegar, shake and test with the indicator under investigation.
3. Continue adding water until no colour change is seen.

Result: Hibiscus indicator paper is sensitive to one drop of vinegar in between 150 and 200 drops of water.

Question:
1. Is hibiscus the most sensitive paper?
2. How can Hibiscus be used to compare the strength of different acids and bases?

Part VI. New Questions

A. If your own investigation has led to more problems continue to investigate those problems rather that starting to answer any of questions 1-10 which follow.

or

B. Examine the questions and problems that you noted on reading the reports on the previous pages. Find ways to investigate these questions and make careful notes of your experiments.

or

C. If you were unable to raise new questions and problems the following are some questions that have been raised by other students:

1. Do flowers contain hidden colours?
2. Are drops of different liquids the same size?
3. Are some liquids heavier than others?
4. What other plant juices can be used as an indicator?
5. What other natural acids and bases are there?
6. How sensitive is a home-made indicator?
7. Oil takes longer to empty out of a tin with a hole in the bottom than water. Is this because oil is lighter than water? Or because it is thicker than water?

8. Can a home-made indicator be used to find out which acids are stronger than others?
9. Why do some colours always spread out farthest or rise higher on strips of blotting paper standing in liquids?
10. Which liquids dry most quickly?

Part VII. Reporting.

Write a final report of your work with liquids.

Related Readings:

For a deeper understanding of the problems you have been working, ask your tutor for a list of recommended reading.

Chapter 2: Strength of Materials

Introduction

There are many things which we use in our daily life without thinking about where they come from, how they are made, or how we might improve them. We cook in metal pots; we transport grain in heavy cloth bags; we live in houses built with a variety of materials. In some cases the most efficient design has been reached through years of experience. Often, however, there are improvements that can and are being made. In thinking about making such improvements, one must think about various aspects such as

What is the best size (neither too big nor too small)?

How much should the piece weigh?

How strong must the material be?

Answers to questions such as these are needed when choosing the proper material to use for any particular purpose. The following activities are concerned with ways of investigating the suitability of different kinds of materials for various purposes. The reader should consider these investigations as starting points from which he or she might go on to more thorough studies of related problems.

Activity 1. The Strength of Metals

Although metals are stronger than most other materials, their properties must be investigated before they can be used in the most efficient way. As an example of such an investigation, consider the following test for the strength of a piece of wire.

Bend a straight piece of wire through a certain angle, a, as shown in the following drawing.

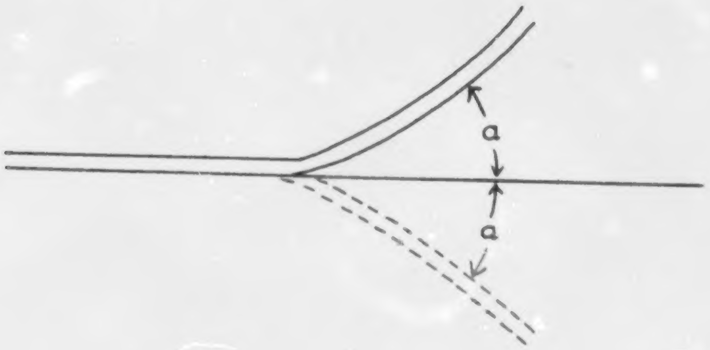


Figure 1. Piece of wire bent through the angle a.

Then bend the wire back to its original position and through the same angle, a, to the opposite side.

Repeat the bending back and forth, and count the number of times the wire can be bent before it breaks.

Carry out this test several times for each of several different angles of bending. For each angle of bending used, calculate the average number of times the wire was bent before it broke.

Now several questions can be answered from a look at your measurements. For example, how does the resistance to breaking by bending depend on the angle through which the wire is bent? It might be useful to show your results by means of a graph. Other questions which may occur to you are the following.

How does the thickness of the wire affect the results?

What would happen if a different kind of wire were used?

Does it make any difference if the bending is done slowly or rapidly?

Suppose we could limit the angle of bending to a very small angle, say two degrees. How many bends do you think it would take to bend the wire? How can a graph of your results help to answer this question?

What other questions have occurred to you as a result of your initial experiments? Such questions can often be answered by more thorough investigation in the classroom.

Activity 2. Measuring the Strength of Materials

In Activity 1, we saw one way in which we may speak of a metal as being strong namely, the ability to withstand breaking by bending. Collect several pieces of metal whose strength you might test. Include in your collection pieces of metals of different kinds and of different shapes and sizes.

Can you think of other ways in which we might think of metal as being strong? For example, we know that it is easier to mould a piece of clay than to mould a piece of metal.

Write down all the ways you can think of in which a piece of metal can be thought of as having strength. Your list should contain five or more ways which we have not mentioned.

1. Resistance to breaking by bending
2. ....
3. .... etc.

Consider now a piece of string. (Collect several pieces of string of different kinds.) If someone asks you for a strong piece of string, what kind of string do you look for? Again, write down the ways you can think of in which a piece of string can be strong.

Are the ways in which a string can be strong the same as the ways in which a piece of metal can be strong?

Once we have defined the way in which a piece of material can be strong, we must then look for ways of measuring that strength. For each of the definitions of strength you have given above, design a way of testing that strength. Try out the method you have designed by testing the strength of the pieces of metal and string you have collected.

After you have tried your method of testing your materials, can you think of ways of improving your tests? For example, do you get the same results when you repeat your measurements for the same material under the same conditions? If your results are not repeatable, you should look for better ways of measuring the strength of the materials being tested.

How will you describe your measurements to other people? Can you express your results in a numerical form? That is, instead of saying that your material is very strong, strong, or weak, can you describe the strength by means of a number which comes out of your measurements? This numerical description of the strength will be of particular importance when you want to compare your measurements with those made by others in different places.

Activity 3. Comparing Strengths of Materials

We have seen that the way we define the strength of a material depends on which material we are considering. Before we look at ways of comparing the strength of materials, let us try to think of several different materials whose strength we might measure.

Make a list of at least ten different materials whose strengths you might investigate. Of those definitions of the strength of materials which you outlined in Activity 2, which ones can be used for each of the materials you have just listed. You might make a chart which shows the kinds of materials in one direction and the kinds of tests in the other direction.

Kinds of materials / Tests	Iron	Wood	Cloth	......
Bending	yes	no	no	?
Pulling	yes	?	yes	?
....	?	?	?	?
....	?	?	?	?

Can you think of other tests of strength which would be appropriate for the different materials you have listed?

Suppose now that you wanted to compare the strengths of different pieces of metal. Proceed to measure the strengths of the pieces of metals you have collected according to the tests you designed in Activity 2. What factors must you consider if you want to compare the strengths of these pieces of metal?

Can you obtain a numerical strength of your sample which is independent of the size of the sample?

Does the shape of the sample affect the measurement of the strength?

Is the same metal always the strongest piece in different kinds of tests?

From the results of your tests, can you think of examples of how different kinds of metals might be better for different kinds of jobs?

You will see that some tests can be used for some kinds of materials and not for others. Choose a test that is applicable to as many kinds of material as possible. Perform this test on those materials and compare the results. Can you think of reasons why some materials are stronger than others for this test? Do some materials have properties in common which make them have similar strengths?

Activity 4. Changing Strengths of Materials

When asked to measure the weight of a piece of wood, a boy in a Grade V primary school science class responded that he did not like to report that measurement. When asked why not, he said, "If I weigh it today, and then weigh it tomorrow, it might not weigh the same."

This boy was already well aware of the fact that measurements of the physical properties of materials depend on the condition in which the material is found. Thus, the strength of a material, however it might be defined, can often be changed by altering the conditions under which the material is tested and the state in which the material is found.

Make a list of as many ways as possible that you can think of in which the condition or state of the material can be changed. Again, a chart can be made which shows the kinds of materials in one direction and the changes in condition in another direction.

Choose one of the materials you have collected, and one of the tests appropriate for that material. Perform this test of the material you have chosen several times, changing a single condition of the material for each test. For example, if you are measuring the strength of a piece of metal, you might make the same measurement after the metal has been heated to different temperatures. Or, you might measure the strength of a certain kind of string after it has been soaked in a chemical for different lengths of time.

Can you show your results in the form of a graph? How does your graph help you to draw conclusions about the material whose strength you are measuring?

How does the same change in condition affect the strength of different materials? Which materials can best retain their strength at high temperatures?

How are changes in condition connected with the passage of time? Under what conditions might a piece of material lose some of its strength over a period of time?

As you continue your investigations concerning the strengths of materials, you will gain experience which will allow you to make some predictions about this area of science. When possible, try to use your past experience to make a judgement about the results of you experiment before you carry it out. Of course, your prediction must be verified by actually performing the tests you have designed.

If your prediction was not fulfilled, what factors do you think you may have neglected to take into account? The ability to estimate what is going to happen even before it happens is one of the most powerful tools which result from the application of the scientific method to solving problems.

Activity 5. Practical Applications

Questions such as those investigated in the previous activities are some of the questions which must be answered by designers of new things. For each test you have performed in the previous activities, can you think of a way in which the results of your test would be useful in a practical application?

Hardening tools* . Perhaps during your investigations you have discovered that the hardness of a piece of metal is affected by the kind of heating and cooling the piece has experienced. Through the process of "heat treatment," the hardness of metals can be increased considerably.

Put two pieces of iron into a charcoal fire. In a short while the pieces will get red hot. After the pieces have reached a red heat, remove them from the fire, letting one piece cool in the air, and plunging the other piece into a bucket of cold water. Which piece is now the hardest?

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*See the Teacher's Guide, "Tools for the Classroom."

Other questions that might be considered are the following.

Is the hardness influenced by the length of time the metal is kept in the fire?

How would the hardness be affected if the piece were cooled in a bath of oil?

Will the hardness be increased if the piece is heated and cooled a second time?

Now take a piece of iron and pound it several times with a heavy hammer. Does the pounding change the hardness of the area pounded? Now put this piece of iron through the process of heat treatment. Has the previous pounding affected the response of the piece to the process of heat treatment?

Many of the treatments can now be applied to metals other than iron. Do all metals respond in the same way to each kind of heat treatment?

Making science equipment for the classroom. When working with children in the classroom, there will be many times when you will need pieces of equipment with which to carry out science investigations. Some such pieces which are often needed are the following:

Animal cages

Aquarium

Balances

Pendulum clock

What are the best materials to use for making such pieces of science equipment? What are some factors you must consider when choosing the material for this work? Can you use locally available materials? Can you discover substitute materials for those which are ideal but expensive or not available?

Building a bridge. Suppose a bridge is needed over a stream 3 metres in width. How many different ways can you think of to build a bridge over such a stream? (Can you give examples of such bridges from different areas of the country?) Some questions which must be answered are the following:

What kinds of materials are needed?

What kinds of materials are available?

What will be the dimensions of the bridge?

How strong must the material be?

Now suppose a bridge is needed across a stream 6 metres in width. What changes in design must be made? Can all dimensions of the bridge be doubled?

These are some of the considerations made by people who have been building bridges for hundreds of years into the past. Which of these considerations do you think are most important for the designers of large modern bridges used by trains, lorries and cars?

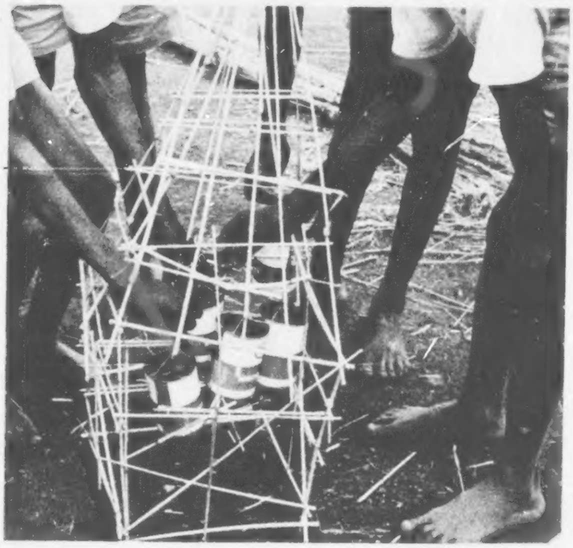
Other applications of testing materials. By now you will no doubt have thought of many ways in which testing the strength of materials can be of practical use. Some further situations you might investigate are the following:

Construction of houses

Making furniture

Transporting goods

These and other tasks you can think of are being carried out every day all around us. How do people near you solve such problems? Discuss some of your investigations with local craftsmen. Important improvements can arise through such discussions and exchange of ideas.



PUPILS TESTING STRENGTH OF THEIR GRASS STRUCTURE

PUPIL TESTING STRENGTH OF SMALL BRICKS SHE HAS MADE

Chapter 3: Changing Systems

Introduction

No matter which aspect of the environment we look at, there are always changes taking place - changes in time, in position, in different forms of energy, to name a few. There is the daily change from day to night, or the longer term changes of the seasons. Temperatures change, the climate changes, the behaviour of plants and animals change. All of these changes affect both the physical and the biological environment.

Through our own intervention, we can induce some of these changes and we often do. Examples of man's intervention in changing the environment are clearing the bush to establish farms and living areas, villages, towns, and cities; damming streams and rivers to create reservoirs, and lakes; and draining of swamps and marshes.

Looking for changes

Many changes take place around us that we hardly notice. Many changes take place on a scale small enough so that they can be reproduced in the laboratory or classroom. One way to study such changes is to bring to the classroom as many of the following items as possible. (It is often an advantage to work together with some of your colleagues.)

fruit
pieces of bread
pieces of meat
seeds
containers - beakers, jars, etc.
wire
nails
buttons (bone and plastic)
source of heat
litmus paper
torch batteries and bulbs

Also set up in the laboratory:

a swinging pendulum
2 or 3 sets of bottles with water
2 or 3 sets of bottles of water from a pond

Examine these materials and look for as many changes as possible which might take place. Many of the changes will be familiar to you. For example, you might expect that nails will rust if left exposed to the atmosphere for a while. But what changes do you expect to take place in the meat, in the bread, in the pieces of plastic, or in the seeds? Under what conditions would you expect such changes to take place?

You may wish to extend your observations outside the classroom for changes taking place in the garden, in the college grounds, or in a nearby stream or river.

Record in your notebook all the changes you observe. This is particularly important because some changes require many days before they become noticeable. Additional changes to observe are given in Part 1 of the related reading that follows.

Classifications of changes

When you begin to record the changes you observe, you may find that it is better to list the changes in some organized way. How are these kinds of changes related to one another? As you attempt to answer questions such as these, you will begin to develop a system of classification of the changes you have observed.

Additional activities which will help you to explore the problem of classifying changes are described in Part 2 of the related readings.

Several categories of changes are suggested. How do the categories compare with the categories you have used when classifying the changes you observed?

Investigating one changing system

Choose one particular changing system for further investigation. For example, you might be interested in the flask of pond water, or in a banana or some meat exposed to the atmosphere. Perhaps you have a piece of banana on which organisms of many colours are growing. What questions can you ask about this changing system? For example, is there only one kind of organism growing, or does each colour represent a different organism?

In such a situation, you may wish to find out more about the growth of fungi. Can you grow the fungus of each colour in a separate dish? Does each fungus breed only on certain materials? Try many different materials under several different conditions.

This kind of investigation could lead you into a whole new field of biology - micro-biology - in which you would investigate the nature of fungi in general. You could investigate organisms such as penicillin, yeast, and vitamin B extracted from palm wine. This field has endless possibilities for investigation. (See Part 3 a in the related readings.)

Instead, your interest may have centered on fruit flies. You might investigate the best conditions for breeding them, or you might look for which food is the most attractive to them. (See Part 3 b in related readings.)

Or you may try growing planarians - any of an order of aquatic flatworms. (See Part 3 c in related readings.)

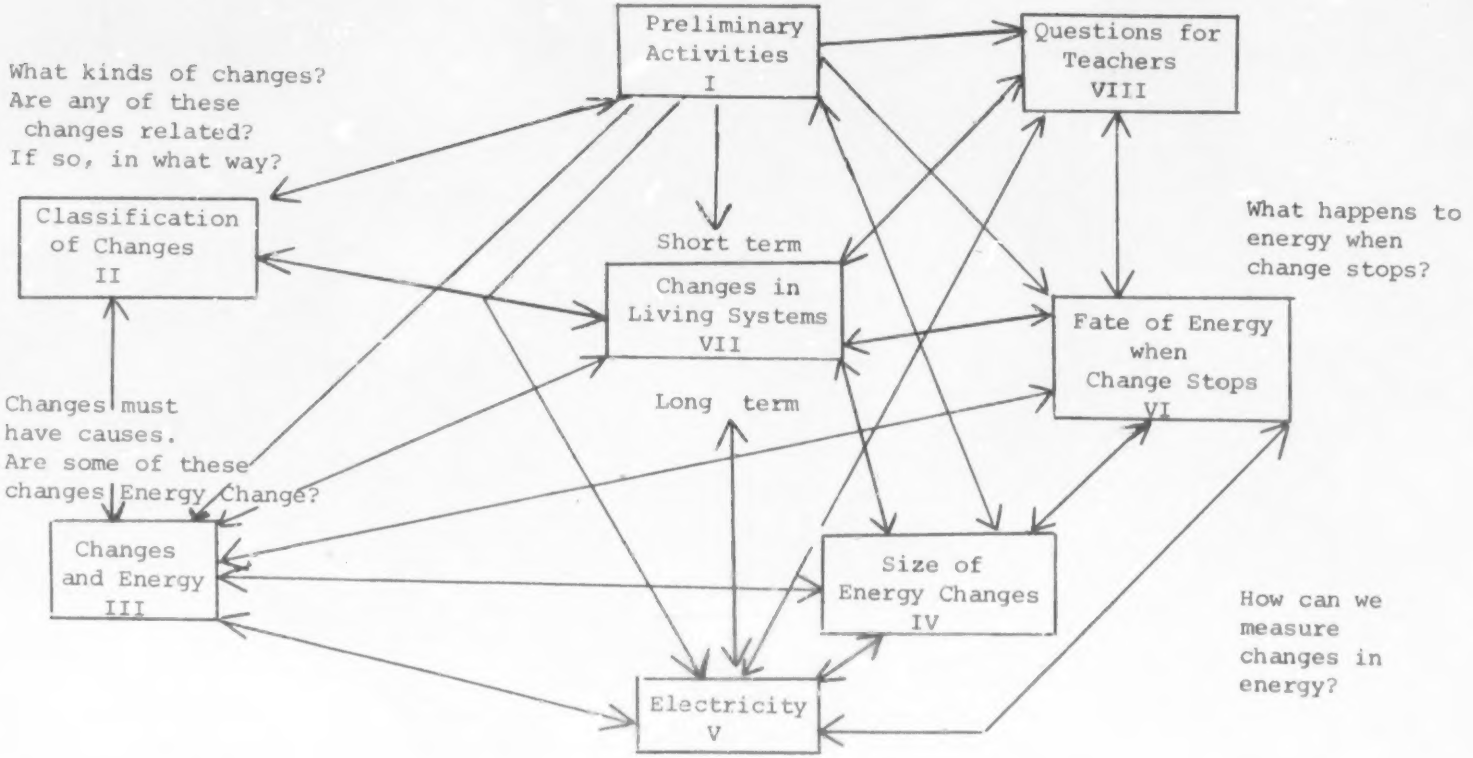
Once you begin to ask questions that can be answered by carrying out your own investigations, you have entered an expanding world of activities and questions, hypotheses and predictions, measurements and data processing - a world which can sustain your interest far beyond the time you spend in the classroom.

On the following page is a flow chart showing some of the ideas we have just discussed. Trace the links between the different parts and then construct a similar chart to show the connections between the topics you have been investigating concerning the theme of changes.

Example 1. You may wish to investigate some procedures of your own for growing fungi. Can a product such as cornstarch be used as a substitute for the "agar" used in laboratories? What other substances encourage the growth of fungi? Can you design a method of measuring the rate of growth of colonies of fungi? What factors affect the rate of growth? What factors affect the development of fungus spores?

Example 2. You may have become interested in the changes taking place in metals, in which case you would have noted different types of changes. For example, you might have noticed rusting, or the oxidation of metals. This might make one think of how metals are obtained from ores. This, in turn, could lead to studies of the production and uses of charcoal and then naturally to the problem of sources of energy in general. (See Part 4 in the related readings.)

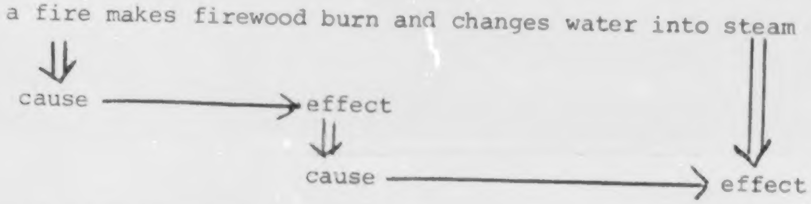
FLOW CHART FOR CHANGING SYSTEMS


Preliminary Activities I
Questions for Teachers VIII
What kinds of changes? Are any of these changes related? If so, in what way?
Classification of Changes II
Short term
Changes in Living Systems VII
Long term
What happens to energy when change stops?
Fate of Energy when Change Stops VI
Changes must have causes. Are some of these changes Energy Change?
Changes and Energy III
Size of Energy Changes IV
How can we measure changes in energy?
Electricity V

You draw some flow diagram to show where your own illustrations might lead.

Example 3. You may have looked at the formation of rust from the point of view of the type of change it represents. How can you prevent rust? Can the process of rust formation be reversed? How is the formation of rust similar to, or different from, dissolving salt in water, the evaporation and condensing of water, the germination of a seed, or the boiling of an egg?

Some changes bring about other changes. For example:



In Chapter 5, Relations and Functions, you will see ways which will help you to study cause and effect relationships concerned with changes.

Some changes you can explore through class discussion are the following.

Putting tea into boiling water - what changes do you observe?

Put milk into tea - what kind of change do you observe?

Put sugar into cold water.

Heat sugar water to boiling - what happens?

Cool water by putting into the freezer - what do you observe?

Try this while using a graduated beaker - what changes do you observe?

Changes do not occur without reason. Changing systems are maintained by a supply of energy. Likewise, energy is detected only because it is involved in bringing about changes. For example, when you put a flame under a beaker of water and leave it there for some time, you notice a change in the temperature of the water - that is, in the degree of warmth of the water. This change in temperature is caused by the transfer of energy from the flame to the water.

Can you design a method for determining the amount of energy gained by the water? How will your method depend on the amount of water involved? How does your method depend on the change in the temperature of the water? Try to apply the method you have designed to the measurement of the transfer of energy to various samples of materials under different conditions.

RELATED READINGS ON CHANGING SYSTEMS

Part 1: Looking for Changes

While carrying out the following activities, look for ways in which things change. Try to bring about changes in as many different ways as possible. Keep a record in your notebook of what you do and see. You will want to refer to these records from time to time. You may also wish to make measurements of some of the changes you observe. Such measurements will be part of your records.

A. Do one or more of the activities suggested below, using the following materials. (Similar materials which are available may also be used.)

rubber bands, various sizes
thin strips of bamboo
bicycle pump
two buttons, or dried, flat seeds
string
stones, various sizes
pieces of cardboard
paper
blocks of wood
candles
thin strips of metal
rubber balls, various sizes
shallow cup
cotton reel
wire
rubber balloons
matches
magnifying lenses
tins

1. Use as many ways as possible to make an object move without pushing it with your hand.
2. Find as many ways as possible of getting a ball, a button, or a seed into a cup without lifting it with your hand.
3. Drop a rubber ball onto a hard surface from different heights.
4. Shoot a stone into the air with a catapult. What happens if you use stones of different weights? How many different ways can you make the stone go higher?
5. Find as many ways as possible to make a block of wood hotter.
6. Find as many ways as possible to make changes in a piece of paper. Which changes can you undo; that is, for which changes can you bring the paper back to its original state?
7. How many ways can you find to make water in a small tin hotter?
8. Make as many changes as you can with a rubber band.
9. Make as many changes as you can with sunlight.

Instructions for testing one possible change are as follows:

In the early morning of a sunny day, choose a green plant near your school. Cover one leaf with aluminium foil or black paper, and leave the plant exposed to the sunlight for about four hours. Pick the covered leaf, and another leaf from the same plant, and test them both for the presence of starch. Compare the appearance of the two leaves before and after testing for starch.

Directions for testing for starch:

(i) Boil the leaf in water for at least five minutes to kill it.

(ii) Put the leaf in hot alcohol for a minute or two to remove the colour. (Caution: Do not heat the alcohol directly with a flame as it may catch fire. Put the container with the alcohol into a large container filled with very hot water.)

(iii) Dip the leaf in hot water to soften it.

(iv) Soak the leaf in iodine solution. (The solution can be made for the whole class by grinding together equal amounts of iodine and potassium iodide crystals, about a pinch of each, and dissolving the mixture in about a pint of water.)

(v) Wash the leaf again and hold it up against the sunlight.

B. Make as many different changes as you can using the materials provided in the following sets:

1. Cotton reels, milk tins, wire, string, rubber bands, cardboard.
2. Ball, bamboo splints, string, bicycle pump.
3. Paper, matches, magnifying lens, metal strips, alcohol.
4. Sugar, water, matches, tin,paper.
5. Candle, rubber band, paper clips, magnifying lens, rubber ball.

C. Go outside and make a list of all the changes that you can find around your classroom.

Part 2: Classification of Changes

In all of the activities that you and other members of the class have done, you have seen a large number of changes.

A. Try to arrange all the changes you have seen into groups, so that all the changes in one group have something in common.

B. Compare your groups of changes with those obtained by other students. Do all their changes fit into your groups? Do all your changes fit into other groups? You may need to make up a different scheme of classification.

C. You have probably seen that it is possible to classify your changes in different ways. We do not often worry about whether a classification system is right or wrong, but whether or not it is useful for a particular purpose. The following is a list of types of changes which many scientists have found useful:

changes in height
changes in movement
changes in compression or stretch
changes in temperature
changes in light
changes in the composition of material

Try to put the changes you have observed into these categories. Discuss your classifications with others. Are there some changes that do not fit into these groups?

Can you make up other groups for them to fit into?

D. Think of some of the things which might have caused each of the changes you have observed. Make a list of all the things that can cause these changes, and classify them.

E. Can you fit most of these causes into the classification you made up in A or B above? Can you fit them into the classification in C that scientists use?

Part 3: Change and Energy

You have seen that every change is caused by something. A ball cannot undergo a change unless it is dropped, pushed, squeezed, thrown, or in some way acted upon. This same relation of cause and effect operates in all situations, although often the cause is not as obvious as the result of the cause. This is particularly true of changes you may have noticed in living systems. For example, people move about, grow and have thoughts. These changes do not take place only because we want them to, but are made possible as a result of the changes that take place when a human being eats and digests food.

You may have noticed that many changes can also cause other changes, and that both of these changes, whether cause or result, can be put into a simple system of classification.

Another aspect of change which may not have occurred to you is that energy is involved in all changes. A change requires the transfer of energy in some form. Energy can appear in different forms, but we detect it only because it is involved in changes.

Following is a table which gives the form of energy which is associated with each of the types of changes which we have discussed.

Type of Change	Energy Change Involved
Height	Potential energy
Movement	Kinetic energy
Compression or stretch	Elastic energy
Composition	Chemical energy
Temperature	Thermal energy
Light	Light energy

Energy is also found in other forms which are less common or less important. Some of these are discussed in related readings.

A. Consider some of the changes involved in your activities.

In each case, work out what changes in energy took place during the process. Discuss these with the rest of the class to see if they agree. E.g., when paper is burned, water is heated. Sometimes energy changes from one type to another. One example is, if paper is burned to heat water, chemical energy has been changed to thermal energy.

Can you think of other examples?

In some cases, the energy change may not involve a change of form. For example, ball A hits ball B (at rest). Ball A slows down or stops, while Ball B is set in motion.

Energy change: Kinetic ⟶ Kinetic

In some cases, one form of energy may be converted into two forms.

Example: burning wood

Energy change: Chemical ⟶ thermal + light

In other cases, the overall change may involve a series of other energy changes.

Example: A boy kicks a football into the air.

Energy changes: Kinetic → elastic → potential → kinetic

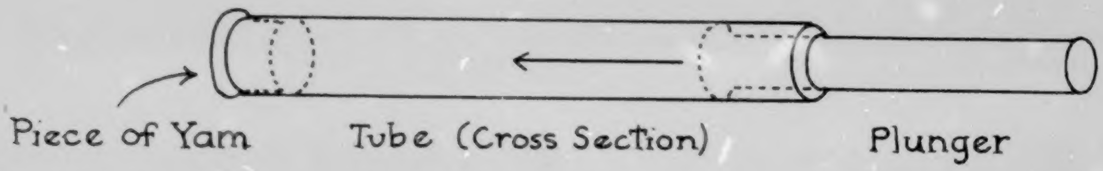
B. Think of some changes that occur in everyday life, such as a car rolling down a hill, a firefly flashing in the dark, movement of a steam-powered locomotive, or an athlete jumping over a bar. Think out the energy changes involved in some of these processes, and see if other members of the class agree with your explanations.

C. Diagrams and instructions for making some games or toys are given on the following pages. All involve energy changes. Make one or more of the games and think out the energy changes which are involved when it works. If you know of any other toys or games which involve energy changes, bring them to class and have your classmates discuss the energy changes which take place.

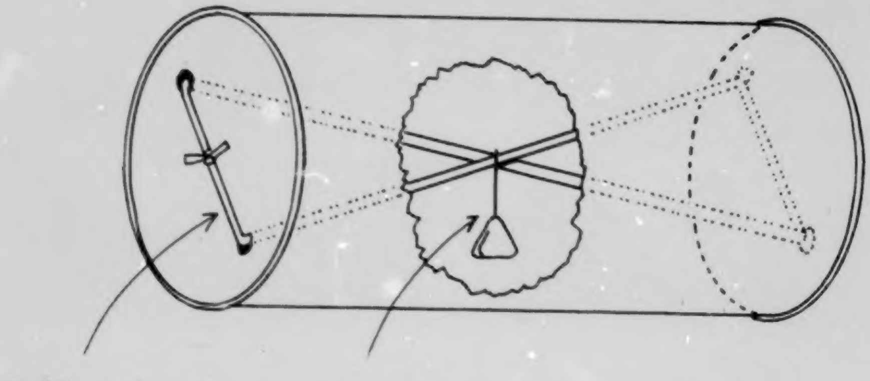
GAMES OR TOYS INVOLVING ENERGY CHANGES

a. Yam Gun

Cut a long, thin tube from a bamboo or reed. Cut a piece of yam or similar material to fit snugly as a plug in one end. Make a plunger from a green stick, just slightly smaller than the inside diameter of the tube, but with one end mashed out like a pounding stick so that it fits into the tube as shown. If the plunger is pushed sharply into the tube, the plug will fly out.


Piece of Yam
Tube (Cross Section)
Plunger

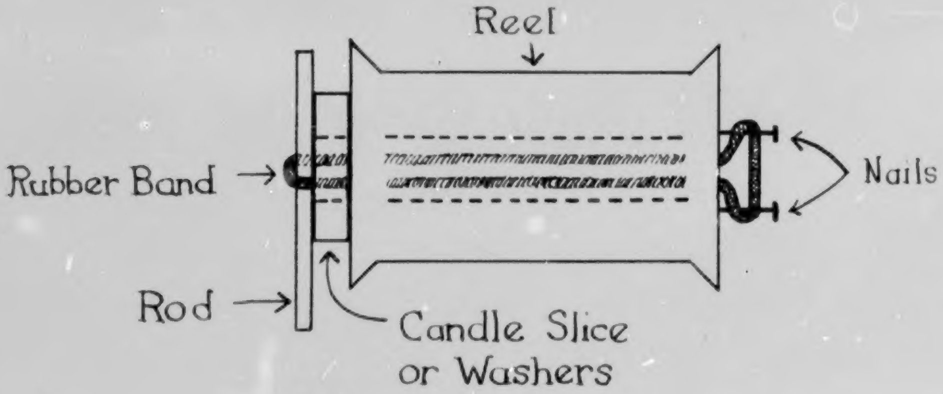
b. Come-back Roller


Rubber Band
Heavy Weight on Wire

You can use either a juice tin or a round tin with a push-in top. Assuming it is a juice tin, cut two holes as shown in each end of the tin and remove the contents. Cut a section from the side of the tin (if a juice tin) in order to insert the rubber band and weight. (If you are using a tin with a removable top, you can insert the apparatus before putting the top back on.) Cut a large, heavy rubber band at one end and thread it through the holes as shown. Tie the rubber band outside the tin at one end. Hang a weight from one strand of the band so that the band twists as the tin rolls in one direction.

c. Cotton-reel tank

Pass a heavy rubber band around two nails attached to the end of a cotton reel and run the band through the central hole of the reel so that the loop just appears at the other end. Put a rod of smooth wood or metal through the loop. The rod should be longer than the diameter of the end of the reel, the length extending beyond one side of the reel. Use the rod to twist the rubber band. The tank should move when placed on a flat surface, so long as there is not too much friction between the rod and the reel. To reduce this friction, put a slice of candle between the rod and the reel, with the rubber band passing through the centre of the candle slice. Alternatively, two metal washers could be used, with a drop of light oil to lubricate them.

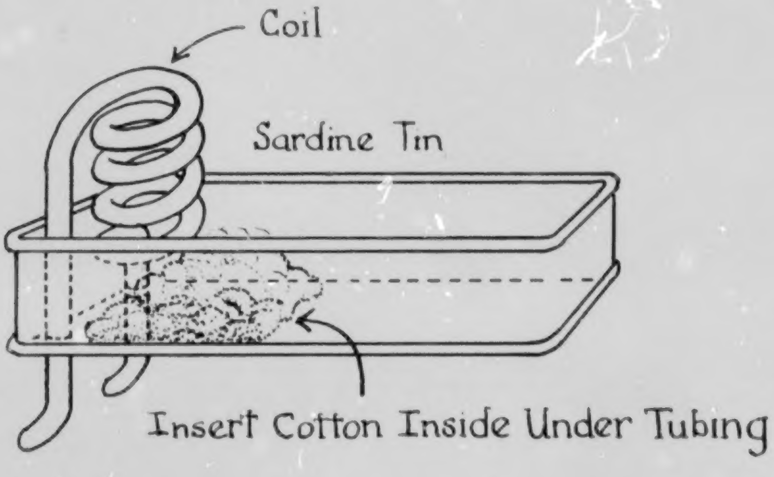


d. Bow and Arrow

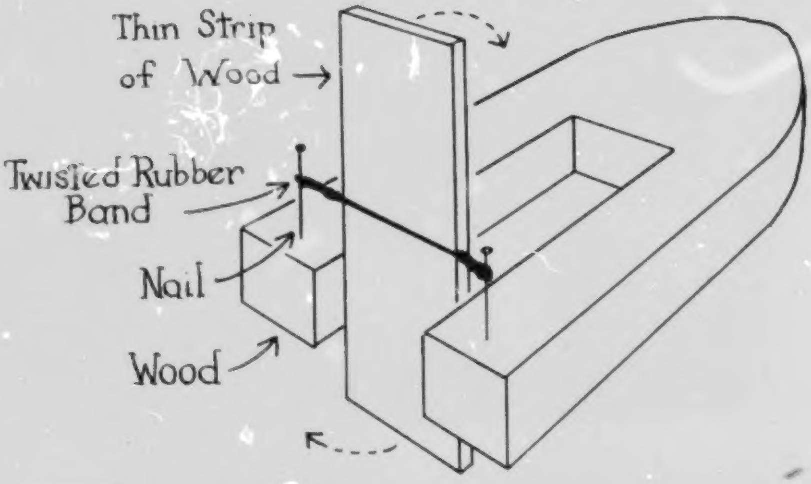
You can make a bow from a strip of bamboo and a string. Any straight piece of wood can be used for the arrow. Notch one end of the arrow so that the string will fit into the notch. The other end of the arrow should not be sharp. Nor should it ever be pointed at anyone.

e. Jet-propelled Boat

Punch two holes side-by-side in the bottom of a sardine tin. Heat a piece of brass tubing until it is red hot and part of it can be made into a coil as shown in the diagram. Fit the tubing into the tin with the two ends going through the two holes you have made. Fill the coil with water, and put it in a pond or a large container of water. Put a piece of cotton wool soaked in methylated spirit inside the boat under the tubing, and set fire to it. After a minute or so, the boat should move through the water.

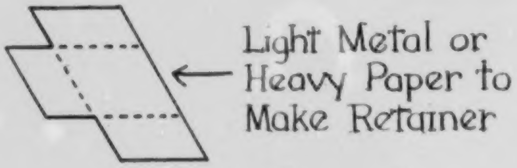


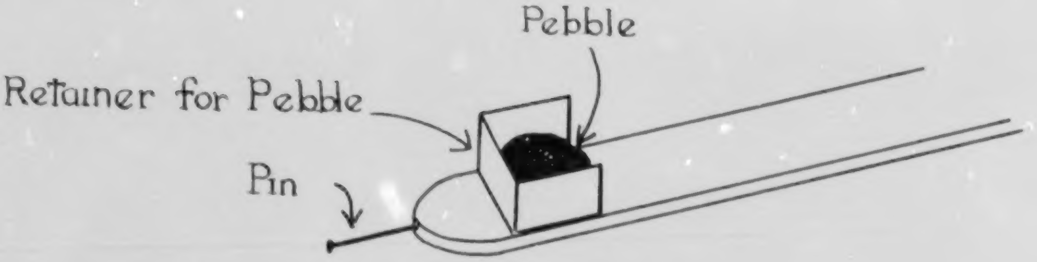
f. Paddle-wheel Boat


Thin Strip of Wood
Twisted Rubber Band
Nail
Wood

g. Mangonel

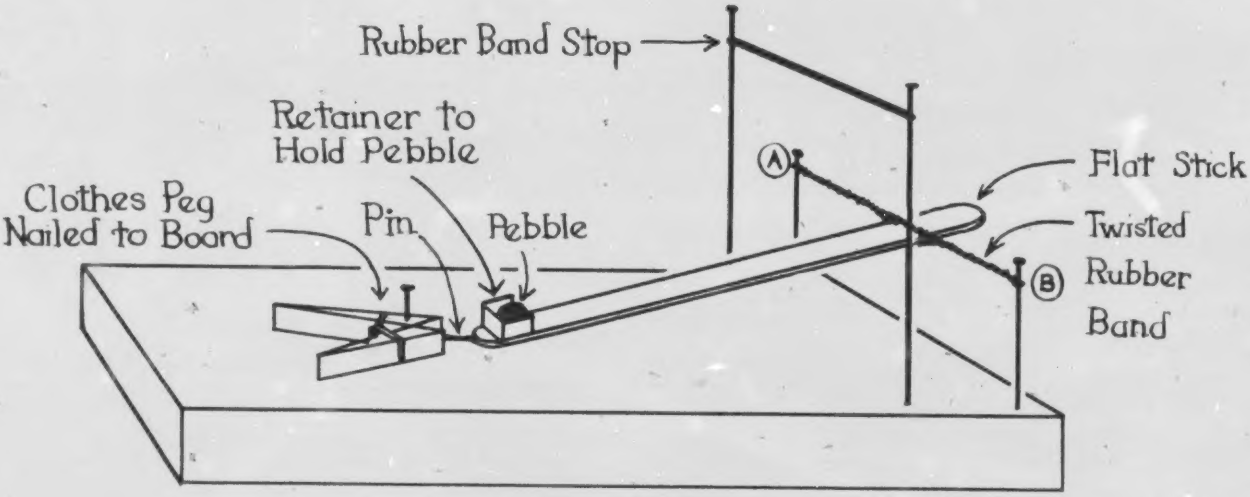
Construct the model as shown on the following page. Note that a pin (small nail) is inserted into one end of the flat stick, and the pin is held by the clothes peg. A holder or retainer for the paddle can be made from a light piece of metal or of heavy paper and attached to the flat stick. See diagrams below.


Light Metal or Heavy Paper to Make Retainer


Pebble
Retainer for Pebble
Pin

g. Mangonel (cont'd)

Hammer in Nail A. Loop rubber band around Nail A. Put Nail B in other end of rubber band and use to twist the band. Then hammer in Nail B. The stick can be slid through the center of the twisted rubber band.


Rubber Band Stop
Retainer to Hold Pebble
Clothes Peg Nailed to Board
Pin
Pebble
A
Flat Stick
Twisted Rubber Band
B

When the flat stick is released by the clothes peg, the pebble will be shot through the air. This is a model of a weapon that was used many years ago. Ropes, rather than rubber bands, were twisted so that heavy rocks could be thrown high into the air for great distances. This was used to break down walls protecting cities.

Part 3a: Growing Fungi

a. Simplified procedures you can use to grow fungi are as follows:

Obtain moist and fresh dung from horses, cows, or other grass eating animals. (Do not touch it with your own hands. Use a piece of wood, long forceps, or thongs.) Moisten a belljar by sprinkling a little water on its inner surface. Place the dung under the moistened belljar and leave in a warm place. In place of the belljar you may use any wide-mouthed glass bowl or bottle. After a few days (2 - 3) a white web develops on the dung. This is the web (mycelium) of the white mould (Mucor).

b. Use a piece of bread or any other starchy or sugary food (garri, maize preparations, rice paste, etc.). Either leave the moistened bread exposed for a few hours or wipe it over the floor. Moisten a belljar (or other large-mouthed bottle) and place it over the bread; then leave in a warm place for a few days. Many moulds will develop, one of which will be the mould Mucor, or Rhizopus. Black dots that appear on the white web are bodies that contain spores. They are called Sporangia. Because of these black Sporangia, these two moulds are usually referred to as 'black moulds.'

c. Keep various fruit juices in uncovered bottles; or just loosely stopper with a loose ball of cotton-wool or cloth. If the juice starts to froth, it means that it is fermenting. This shows that a yeast is present. Any such fermenting juice may be used, therefore, as a source of yeast. Alternatively, palm wine that is actively bubbling may be used as a source of yeast.

To make a culture of a yeast, add a few drops of the fermenting juice to a 5% solution of sugar. You can make the sugar solution as follows: dissolve 5 grams of sugar in a very small amount of water and then add more water to make 100 cc.

d. Nutrient jelly (useful for culturing bacteria): Make a starch paste by first mixing cassava or corn or potato starch in a little cold water and then pour boiling water on gently while stirring, until you get a light paste. Pour into sterilized dishes while still hot and allow it to set. If you do not have ready-made starch, you can use cassava, yam or potato. Then you should scrape the cassava (or yam, or potato) into a pan, cover it with a little water, and boil gently for about three hours, adding water as needed. Strain the fluid through muslin into sterilized vessels (dishes, bottles, watch-glasses, or tubes) and allow it to set into a jelly on cooling.

If you pour any into tubes, place them in a slanting position for jelly to set. When you have poured the jelly, immediately cover the dishes with similar ones (if you have used flat dishes) or plug the mouths of the tubes or bottles with singed cotton-wool.

Such jellies may be used to culture bacteria or moulds. To pick bacteria or mould use a brush that has been sterilized in boiling water, or a needle or long pin that has been heated in a flame and allowed to cool without touching anything.

Part 3b: Growing Fuitflies, also called Banana Fly, or Vinegar Fly

If you wish to grow fruitflies you will need to collect them from the surfaces of fruits like oranges, bananas, plums and so on. You should prepare the culture medium as follows:

i) use cooked maize meal
    treacle
    yeast or piece of over-ripe banana
    several bottles of equal sizes and having wide mouths (e.g. half-pint milk bottles, vaseline bottles, baby food bottles, or jam jars)
    ether for anaesthetising the flies before you examine them

ii) Alternatively, you can use

    mashed over-ripe banana or other sugary fruit like orange (although this may not be as satisfactory as the banana)
    the set of bottles and the ether

Place the bottles in a deep pan with water,bring them to the boil and allow to boil for half an hour, in order to sterilize them. Alternatively, you may use a steam oven for one hour.

Prepare the food by adding together equal quantities of the cooked maize meal and treacle, with some yeast or a piece of over-ripe banana. Place in the culture bottle enough food to cover the bottom evenly to a depth of 1 cm (about one third of an inch).

Make a platform for the flies by standing long pieces (strips) of paper on the food.

With scissors or forceps, pass a fairly large piece of cotton-wool over a flame to singe it. This will be the plug for the bottle.

When you have introduced the flies into the bottle, plug its mouth with the cotton-wool. Then cover it over with grease-proof paper and hold this in place with a rubber band or thread.

Leave in a safe place. New flies are produced within a fortnight (two weeks).

In order to examine the flies, anaesthetise them with ether first. Use only the ether vapour, not allowing the flies to get in contact with the liquid. They remain anaesthetised for about five minutes. To transfer the flies from one bottle into another, place the bottles mouth-to-mouth and let the bottom of the new bottle point towards the light. The flies will move towards the light and hence will move into the new bottle.

Part 3c: Growing Planarians

Find a dead frog or toad

Split it open and leave it in a stream or pond.

Alternatively, you may use a bottle containing boiled pieces of earthworm in place of the dead frog.

Examine the next day to see if you have attracted planarians on or near your material.

You can keep the planarians in an aquarium and feed them with bits of meat.

See APSP unit "Tilapia" for instructions on how to set up an aquarium.

Part 4: Size of Energy Changes

A. You found in your preliminary activities on changes, that it usually took a change to cause a change. We might say now that it usually takes an energy change to produce an energy change. Go back to one or more of your preliminary activities and try to get some quantitative information about how much energy is needed to produce a certain change. Try to get information which would allow you to decide which of the following statements is most likely to be correct.

1. The greater the initial energy change, the smaller the final energy change.
2. The greater the initial energy change, the greater the final energy change.
3. There is no relation between the initial and final energy changes.

Try to get evidence which is as persuasive as possible. You can assume that a larger change requires more energy than a smaller change does.

B. Find out if the rest of the class agrees with your answers to the following questions:

1. In your preliminary activities, did you find that it was possible to make any change without using energy in some form?
2. Did you find that it was possible to use energy, but to get no change at all?

Part 5: Electricity

A. Electricity is not a form of energy, but something which allows energy changes in one place to cause changes in energy at a distant place. There are two main ways which are used by African countries to generate electricity:

1. Hydro-electric power

   Water behind a dam flows downward into a turbine. The flow of water causes the turbine to rotate like a fan.

This turns a set of wires between magnets which causes electricity to flow in the wires. This flow of electricity can be transmitted over great distances through wires and can make changes at its destination. Analyse the change in form or energy in the above process, starting with water behind the dam.

2. Burning Fuel

Oil (sometimes coal) is burned and heats water to steam. The steam turns a turbine, and the rest of the processes follow as above.

B. Think of changes which involve electricity, and ask other members of the class to analyse the energy changes taking place. For example, electricity may be used to run a fan or to light a house.

Part 6: When Change Stops, What Happens to Energy?

A. Turn a bicycle wheel rapidly, then stop it with your hand or the hand brake. What has happened to the kinetic energy of the wheel?

B. What happens to the original form of energy in each of the following situations? If you don't know, do it to find out.

1. A heavy block of metal slides down a ramp.
2. A heavy piece of rubber is stretched and released a number of times.
3. A screw is screwed into a block of wood.
4. Grass decays.
5. Light from the sun strikes an object.

6. A battery is short-circuited.

The above examples were chosen so that the change may be detected. In many other situations, the final form may be produced slowly or lost so rapidly to the air that it may not be detected easily.

Part 7: Energy Changes in Living Systems

A. Plants grow. This change must require energy. Consider the following questions concerning the source of energy for the growth of plants, and what plants need for growth. You may already know the answers to many of the questions. If there are any questions for which you are not certain of the answer, or if there is disagreement, design and carry out an experiment to get the answer. You should remember to use a "control" for each experiment. This means that if you want to test the effect of condition A on a plant, you must have at least two plants, or preferably two groups of plants, one of which is treated with condition A, while the other is not. The two sets of plants must be treated exactly the same, except for the presence or absence of condition A.

Experiments can conveniently be carried out on bean seedlings, which germinate and grow readily after the beans have been soaked overnight in water. Groundnuts also work well, but take longer to germinate.

1. Which of the following are necessary for plant growth?
   - a. Heat
   - b. Sunlight
   - c. Wind
   - d. Water

e. Air (Are certain gases found in air, such as carbon dioxide or oxygen, needed?)

f. Soil (Is soil itself necessary, or just certain things in the soil? Anything which might be present in sand, for example, can be removed by boiling it several times with water, and pouring off the hot liquid each time.)

2. Some things may be necessary for plant growth because they provide energy. Other things may be needed for other reasons. Which of the things that you found necessary do you think provide energy? Can you get any evidence to support your conclusion?

B. Animals grow, and therefore require energy. From your own knowledge, which of the following are needed for growth? Give examples to support your conclusions for each case.

a. Water
b. Sunlight
c. Heat
d. Air (certain gases?)
e. Food

Which of the above provide energy? What differences are there between plants and animals in their sources of energy for growth?

C. How do plants and animals use energy? From your own experiments and observations, state which of the forms of energy we have discussed are involved in the life and growth of either plants or animals or both. Give at least one example of the use of each form of energy. For example, the movement of animals involves kinetic energy. Do plants also move?

D. Investigate one or more of the following systems:

1. Boiling water
2. Boiling an egg or some starch

3. Tides
4. A web being spun by a spider
5. A termite mound being built
6. A seed germinating
7. Larva - pupa - imago
8. Rocks - pebbles - sand

Try to get evidence from each system which would allow you to answer the following questions:

a. What changes occur?
b. Is the changing system living or non-living?
c. What things influence how fast the changes occur?
d. Do the changes require energy?
e. How do the changes you observed differ from growth?

Part 8: Questions for Teachers

Discuss the following questions with others in your class:

1. Is it easy to define "energy"? How can you define it?
2. What would you do if a child asks, "What is energy?"
3. What do you think that a class 3 pupil understands by "energy"? What does a class 6 pupil understand?
4. Is it useful for a teacher to know about energy? Why? What should he know?
5. What should an elementary school pupil know about energy? What will he find useful to know about energy after he has left school?

Chapter 4: Motion

Introduction

Motion can be a rich, varied and interesting area of science to investigate. It doesn't matter at what point you start, the study can lead from one point to another in a complex and interconnected way. The big problem is where and how to begin.

Instead of telling you where or how to begin, an account of how one group of students tackled the topic could serve as a guideline.

How they got started

The first time the group met to consider this topic the tutor in charge had nothing specific in mind. He simply asked the students what ideas they had about what could be studied under the general title, "Motion." To begin with the students were rather surprised. But after a while they slowly started to come forth with ideas. As each idea was mentioned the tutor wrote it on the blackboard. For example,

Animal motion, - fish, dogs, insects, snakes, leeches, etc.

Motion by machines, - cranes, boats, catapults, tops, swings, etc.

Soon there was a long list of ideas on the blackboard that could be studied. When the flow of ideas stopped the group was left with the problem of what to do next. They decided to spend some of their free time before the next class collecting materials that could be used to study some of their ideas. They then spent the rest of the lesson organising themselves into groups based on what people wanted to study. They discussed where various materials could be collected.

How the group continued

The group that had decided to study motion in animals went to a local river. They returned with jars containing fish, leeches and a variety of water beetles. They spent the rest of the period setting up aquariums and observing their animals as they moved.

Others collected materials for making catapults and slings and spent the lesson making a variety of these objects for further investigation.

One group started to make model boats, another group model cranes, a third group made tops, while a fourth group began to investigate pendulums.

As each group started to work with their materials, they began to meet unexpected problems and to ask questions. Work continued for some 8 to 10 hours. For example, the group working with animals became deeply involved with trying to show that when animals move they push backwards. They spent hours unsuccessfully putting clay, paint and a variety of dyes in water to see if they could observe any trace of the patterns fish leave as they swim. They watched the tracks beetles made as they walked on the powdered clay. Together with a small group of children they played games walking on sand and watching dogs walk on sand to find out what could be learned from this activity. Eventually they built an enormous balance made of bamboo that measured how much people pushed back on the ground as they ran, jumped, hopped, etc.

To give a better idea of how each group worked, some of the work of two groups of students is described below - the group that worked with pendulums and the group that worked with tops.

A. Exploration With Pendulums

Excerpts from report of Group A: Despite the simplicity with which it can be constructed, the pendulum is an unusually fascinating and complex gadget. Many standard explorations of the pendulum exist in physics text books, and these would form interesting exercises. These include:

1) The effect of length on the period of swing.
2) The effect of amplitude on the period of swing.
3) The effect of the weight of the bob on the period of swing.
4) The use of the pendulum as a timing device.

A more complex investigation is, "How does the Speed of the Pendulum change from one end of the swing to the other?"

The basic problem is, how can one get visual evidence of any change in speed?

One thing can be established on a logical basis; namely, since the pendulum starts from a position of rest, and moves to another position of rest, it is reasonable to say that the speed first increases to a maximum and then decreases to zero.

It also seems reasonable to expect that the variation in the speed of the pendulum will be symmetrical about the mid-point. However, the tendency of our results not to be symmetrical about the mid-point provided the central problem of our investigations.

The attempt to get visual evidence of the variation in speed using easily available materials can lead to a large number of interesting problems as the full report of the group that worked on this problem shows. (A report written by one of the students in this group is included in Chapter 3, Section II).

Consider now the four problems (mentioned in the report of these students) concerning pendulums. For each problem, design suitable experiments which will give conclusive answers to the problem.

When these students designed an experiment and collected data to find out how the speed of the pendulum changes from one end of the swing to the other, they discovered that their results were not symmetrical about the mid-point. Why do you think this was so? Design your own experiment to investigate this problem. How do your results compare with the results obtained by these students?

What other problems have occurred to you while investigating the motion of the pendulum? For example, how do you think the pendulum in Figure 1 would move when released?

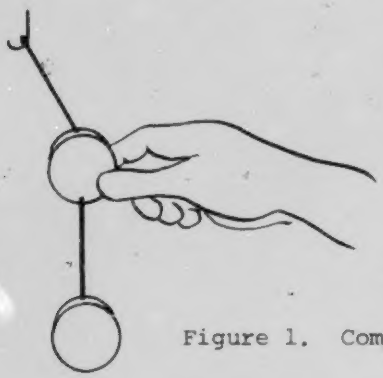


Figure 1. Compound pendulum.

Many of the questions asked about the simple pendulum can now be investigated with regard to this compound pendulum. What new questions can you think of concerning the compound pendulum.

What do children think about pendulums?

Studies of children's ideas about pendulums have shown that children in the age range of 9 to 14 years often have a very complex system of concepts about motion. Many children have a great deal of direct experience of periodic motion through swinging on ropes and various kinds of swings.

Bring a group of children to the classroom and provide them with the chance to play for a while with a variety of pendulums. After they have had ample time to become familiar with the pendulum, show them a pendulum behind which you have placed a paper background (mounted on a cardboard or blackboard) as in Figure 2.

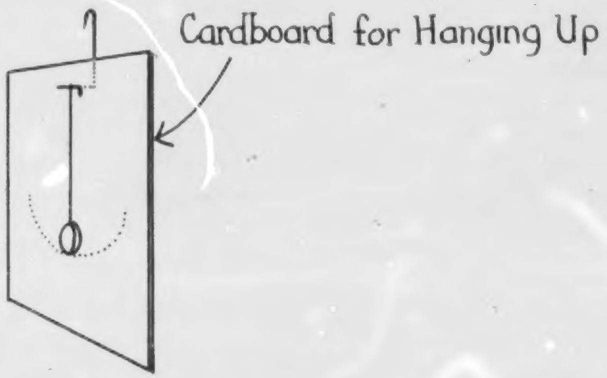


Figure 2.

Let the children watch the pendulum bob trace out a path through an arc of at least 45° on either side of the vertical position.

You can either trace the pendulum path ahead of time, then release the pendulum through the same path, or, perhaps you can think of a method to make the pendulum mark its path as the children watch.

Now pull the bob to one side and ask the children what will happen when you release it. What kinds of ideas do the children talk about? Do they talk about the speed of the pendulums? Do they mention the weight? Do children of different ages talk about different things? Let the children make a bar graph of some of the quantities they mention. During this kind of exercise you will learn not only something about pendulums, but also about how children of different ages see the world around them.

B. Explorations with Spinning Tops

Materials for making tops are commonplace. The activity of designing and making beautiful and efficient tops provides many opportunities for developing skills in:

i) determining what are the relevant variables,
ii) quantifying, recording, and interpreting data,
iii) developing experimental techniques.

In addition, while working with tops, experiences can be gained that furnish a more secure basis for further reading and discussion of concepts such as centre of mass, symmetry, precession, inertia, etc.

One group of students also explored some of these areas with children. The experience indicated that the topic would also be a worthwhile area for younger people to explore.

Excerpt from an Account of Investigations on the Construction of Tops

From the data we collected on the above topic, it appears that the following types of materials are suitable for making tops: soft wood, hard wood, plasticine, wooden spindle, candle wax, bee wax, small seeds, palm kernels/nuts, hard seeds, small nails.

Observations:

1. i) Soft wood was easy to work with but the pith, being very soft, could not support metal points inserted to facilitate smooth spinning.
   ii) Hard wood required a longer time to work with, but was more solid in form and could support metal points inserted at the base.
   iii) Palm kernels were the most difficult materials to work with because they required a lot more time and skill to shape and drill in order to make a well-balanced top.
   iv) Plasticine was the most simple material to work with because it was easy to handle, to shape, re-shape, fix a spindle in and a spinning base.
2. The amount of wieght placed on a top has a definite effect on its performance.
3. The position of the weight on the top affects its performance.
4. The shape of a top affects its performance.
5. The kinds of surface on which a top spins affects its performance.
6. The length of the spindle affects the performance of a top.
7. The size of the spindle must be in proportion to the size of the top.

Consider again the observations made by this group of students. Design experiments which will investigate each of the seven statements or observations they have made.

What are some of the considerations you might make in designing your experiments? For example, what measurements will you make concerning a spinning top? What other conditions might affect your results?

What do children think about tops?

Present a group of young children with a variety of tops, and the materials from which they can make tops of their own. Again, observe how the children respond. Are they already familiar with the concept of spinning things? What ideas do the older children have that the younger children do not yet have? Do the children tend to learn from each other? Every observation of a group of children working, or playing, is liable to give a deeper insight into the development of children, their special nature and their special needs.

We have now considered briefly two kinds of motion - swinging motion and spinning motion. What other kinds of motion can you think of? What other problems concerning motion can you think of? For example, what happens if an object is both spinning and swinging at the same time?

The reader is encouraged to design his or her own experiments that will give a better understanding of different kinds of motion under different circumstances. At the same time, a primary school teacher should always keep in mind how these ideas are related to working with young children.

Chapter 5: Relations and Functions

Introduction

We often notice that when one thing happens, another thing seems to happen as well. For example, most children learn at an early age that when a female animal has become fatter than normal, she may give birth to a baby animal. Or, in some areas people say that when a certain kind of ant is on the move in long columns, it is a sign of rain. It often is!

Such observations of "events" in our surroundings make us suspect that there is some connection between two or more events that take place. One of the most important parts of science is the search for these connections. The series of activities that follow are meant to help you develop effective methods, or tools, for finding relationships among the variety of natural phenomena that take place around us. These relationships often give us valuable clues which help us to solve a problem in which we have become interested.

Several simple investigations are suggested. However, the reader is strongly encouraged to watch for areas of study which he or she finds particularly interesting. The reader should then design and carry out specific investigations which will help him or her to learn as much as possible about those areas of interest chosen for study.

In most cases such investigations must be designed by the person or persons who are going to carry out investigations. This design includes asking the proper questions, deciding how to collect the experimental data, as well as designing and building or collecting the necessary apparatus.

Experimental results obtained during the course of the investigation must be analysed in order to begin making tentative conclusions about the problems we set out to solve. A careful analysis of the experimental data and situation often leads to new problems to study. Solving problems in a scientific way should be seen as a continuous process in which each person should participate fully. Thus, rather than being merely a study of the achievements of others, science education can help us to acquire powerful tools to use in the process of scientific problem solving.

Activity 1. Relations Between Sets of Objects

Following are three examples of two different sets of objects. Collect these sets of objects according to the instructions given below. In each example, can you see any relationship between the members of the first set and the members of the second set?

A. Leaves and seeds.

Set 1. Leaves. Collect a large variety of leaves found around your school. Bring to the classroom only one specimen of each kind of leaf in your collection.

Set 2. Seeds. Collect a large variety of seeds found around your school. Bring to the classroom only one specimen of each kind of seed in your collection.

B. Flowering plants and flowers.

Set 1. Make a list of the flowering plants growing near your school.

Set 2. Flowers. Make a collection of the flowers from the plants of Set 1. Bring several flowers from each plant to the classroom.

C. Flowering plants and insects.

Set 1. Flowering plants. Make a list of the flowering plants near your school.

Set 2. Insects. Observe the insects that feed on the flowering plants near your school. Make a list of as many different kinds of these insects as possible.

How many different kinds of relationships do your fellow students/teachers see? Do they agree with your description?

How did your relationships differ in examples A, B, and C?

Can you find an effective way of describing each of the relationships you have identified by means of a diagram?

Discuss the answers to these questions with your colleagues. From such a discussion may emerge a system of classifying the kinds of relations which can exist between different sets of objects.

Three more examples of two different sets of objects are the following.

D. Children in two different classrooms.

Set 1. All the children in the first class of a nearby primary school.

Set 2. All the children in the last class of a nearby primary school.

E. Students and their home districts.

Set 1. Let Set 1 consist of all the students in your class.

Set 2. Make a list of all the areas of the country (provinces, or districts, etc.) from which students in your class might come.

F. Students and activity clubs.

Set 1. All the students in your class.

Set 2. Make a list of all the activity clubs at your school.

In each pair of sets how does the relationship between the members of the two sets compare with the relationships you identified in examples A, B, and C above?

How many kinds of relationships have you now identified?

Make a list of several examples of each kind of relationship you have identified. Have you changed your system of classifying your relationships?

One system of classifying the relationships which can exist between the members of two different sets is the following.

One-to-one mapping. Consider the following circumstances concerning a certain primary school.

1. There are seven classes of children in the school, and seven teachers, one teacher assigned to each class.
2. There are 30 children in each class, and 30 seats in each classroom, one seat for each child.

Here we see two examples of a connection between two different sets of "objects". In 1., how many teachers are assigned to, or correspond to, each particular classroom? In 2., how many children are assigned to, or correspond to, each seat in the classroom? In both cases we say that there is a one-to-one correspondence between the members of the two different sets.

Another way of speaking of such connections between the members of two different sets of objects is evident from the diagrams in Figures 1, and 2. In Figure 1, a line is drawn from each teacher to his or her classroom.

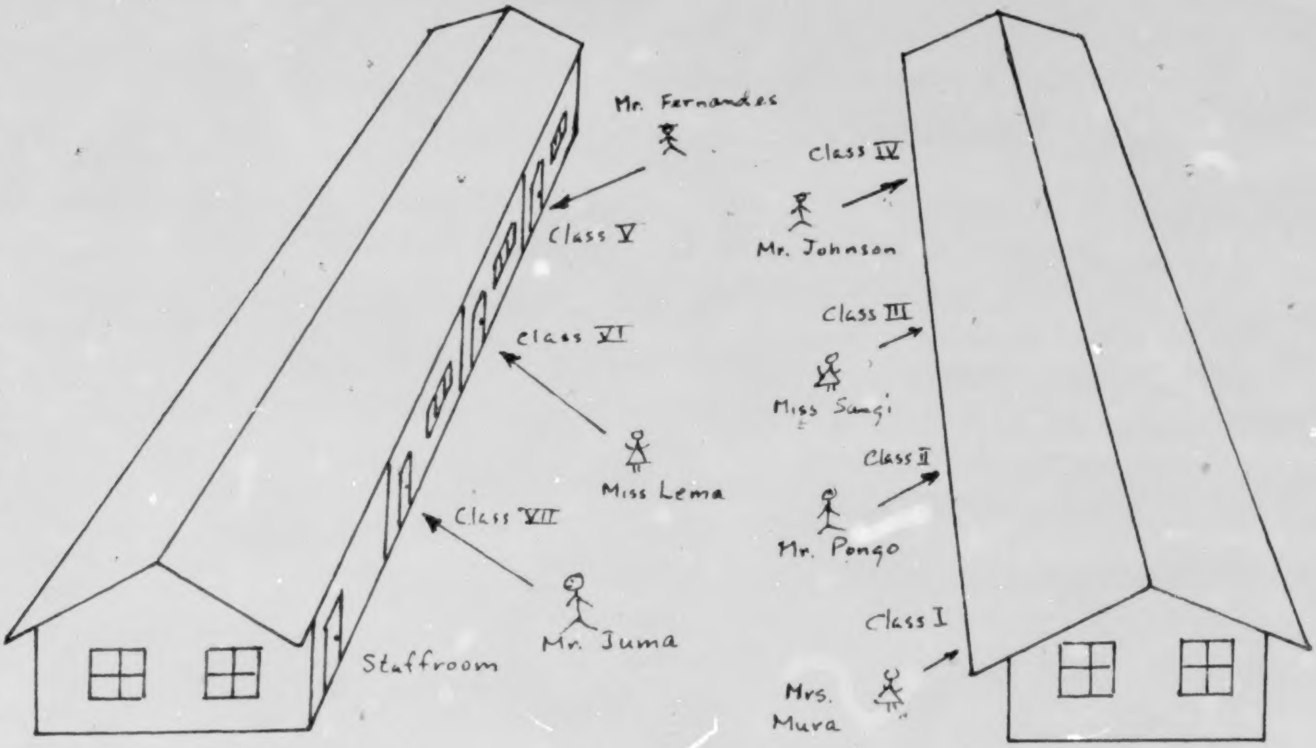

Mr. Fernandes
Class IV
Class V
Mr. Johnson
Class III
Class VI
Miss Sangi
Class II
Miss Lema
Class VII
Mr. Pongo
Class I
Mr. Juma
Staffroom
Mrs. Mura

Figure 2. Mapping of the set of teachers on to the set of classrooms.

Thus we can say that there is a mapping from the set of teachers to the set of classrooms. Similarly, from Figure 2 we can say that there is a mapping from the set of children to the set of seats in the classroom. As you might expect, these are both examples of a one-to-one mapping.

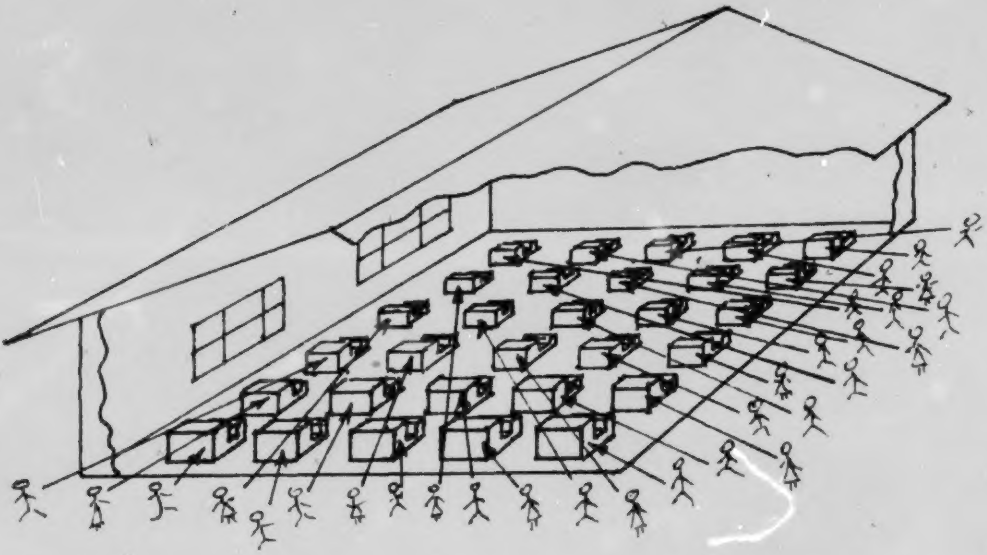


Figure 2. Mapping of a set of 30 children on to the set of 30 seats in the classroom.

Were any of the relationships you identified in the previous examples of this type? What changes could you make in the sets from the previous examples to make a one-to-one mapping possible?

Many-to-one mapping. Let one set be made up of the children in a certain village, and the second set of the fathers of those children. How many members of the first set (the children) might be assigned to each member of the second set (fathers)? How many members of the second set might be assigned to each member of the first set? In this case we speak of a many-to-one correspondence between the two sets. Or, as we see from Figure 3, we can make a many-to-one mapping.

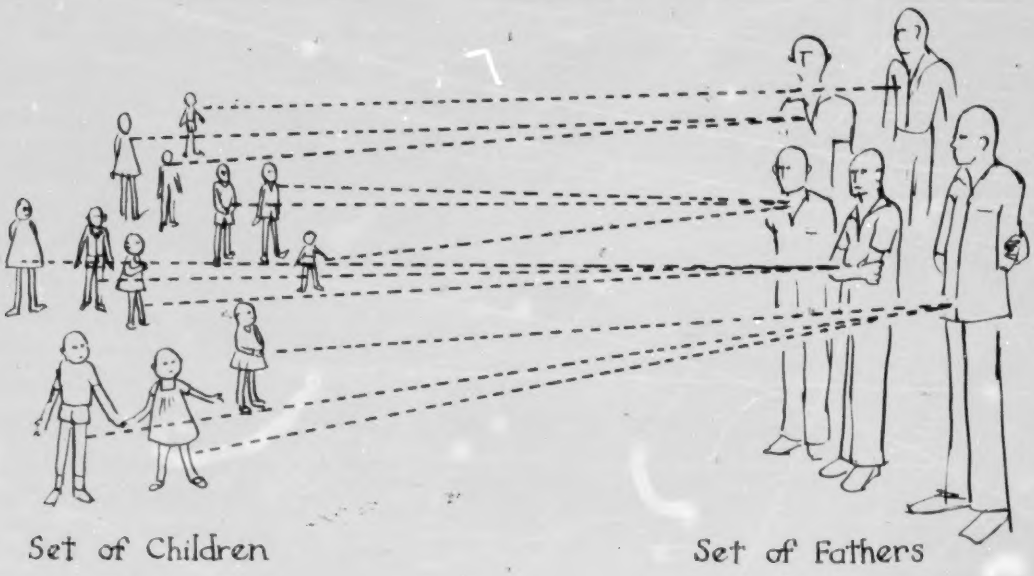


Figure 3. Many-to-one mapping between the set of children and the set of their fathers.

Many-to-many mapping. Consider now the mapping of the set which consists of common diseases found in society to the set whose members are the inhabitants of a certain village. Can you explain under what circumstances this might be an example of a many-to-many mapping between two sets? Draw a suitable diagram.

Consider now the relationships you identified when comparing the pairs of sets in the previous examples, including those examples furnished by you. Do they fit into the categories of one-to-one, many-to-one or many-to-many mappings? If not, how might they be changed so that they do? Again, discuss these questions with your fellow students.

Try to think of as many examples as you can of the different kinds of mappings. Draw your examples from a variety of different fields of interest. For example, consider the marriage laws in different societies. How do marriage laws in a society "map" the two sets, male and female, with respect to marriage?

A thorough understanding of the ideas connected with mapping between different sets of objects will help to understand more complicated relationships met in further scientific studies of many different kinds.

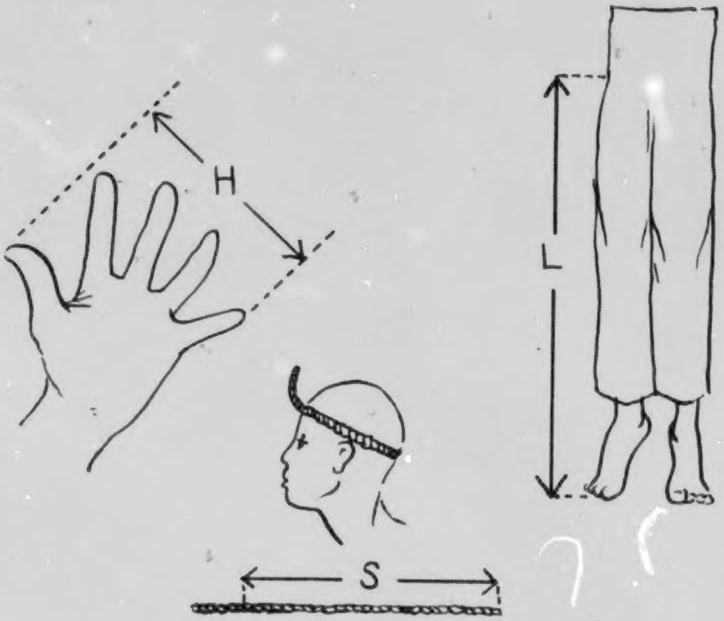
Activity 2. Relations Between Sets of Measurements

Another type of mapping which is often useful is the mapping between two sets of measurements. Following are three examples of sets of measurements between which we might establish useful relationships. In each example, watch for questions which might lead to further investigations of the area of study concerned.

A. Patterns of Growth of Human Beings

Perform the following four measurements for yourself, and for several other people of different ages, including small children.

Measurement 1. Spread your hand as wide as you can. Measure the distance from the tip of your thumb to the tip of your little finger. Call this



distance H.

Measurement 2. Measure the length of your leg, from the tip of your foot (with your toes stretched downwards), to the top of your thigh. Call this distance L.

Measurement 3. Using a piece of string, measure the largest circumference around your head. Call this distance S.

Measurement 4. Record your age.

When you have performed these measurements for several people, you will have four sets of measurements among which you can attempt to establish various relationships. How can you make a one-to-one relationship, or mapping, between any two sets of measurements?

What do the relationships you have established tell you about the process of physical growth of a person? For example, what is the relationship between the measurement of S, the circumference of the head, and the age of a person?

You can show your relationship in a useful way by means of a graph. For example, make a graph by plotting the value of S against the corresponding age for each person you have measured. How might this graph help you to discover more about the relationship between head size and age?

Or, you might plot the value of H against the corresponding value of L for each person in your sample. How might such a graph help you learn more about the relationship between H and L?

Each value of L can be divided by the corresponding value of H. Let us call this ration of L/H by the new label R. Suppose you make a graph by plotting R against L. What does this new graph tell us about the relationship between L and H.? How is this graph related to the previous graph?

What are some of the questions that occur to you concerning these sets or measurements? For example,

> How does the process of growth differ between an infant and a ten year old child?
>
> Does everyone of the same age grow at the same rate?
>
> Do all parts of the body grow at the same rate?
>
> What would the results be of similar measurements made of different kinds of animals?

By increasing the number of individuals measured in your sample, you may learn more about patterns of growth. For example, you may find that the measurements for some individuals differ considerably from the average value. Or, in some cases the measurements for a group of individuals are quite different from the usual pattern. The reader is encouraged to use his or her data as a starting point for a more comprehensive study of the growth patterns of human beings as well as of other living things.

B. Identification of Plant Species

Collect a large sample of leaves (at least 50) from a bush or tree. Measure and record the length and width of each leaf in your collection. Call the length L and the width W.

What relationship do you see between the length and the width of the leaves you have collected? Make a graph of the length, L, against the width, W, for your set of measurements. How does this graph help you to see more clearly any possible relationships between L and W?

Each value of L can be divided by the corresponding value of W. Again, call the ratio L/W by the new label R. Make a graph of R against L. How is this graph related to the previous graph? Does this graph tell us anything new about the relationship between L and W?

Collect the same number of leaves from another bush or tree of the same species as the first collection. Measure and record L and W for each leaf, calculate the ratio R, and make a graph of R versus L as before. How does this graph compare with the graph for the first collection? (Figure 4 shows the results of such measurements for two different Bouganvillea bushes, one with pink sepals, and the other with white sepals.)

Now collect leaves from a similar, but slightly different bush or tree. Perform the same measurements and make a graph of R versus L. How does this graph compare with the first two graphs? To what might you attribute any differences?

How can such graphs be used to determine slight differences of plants within the same species? Or between similar species?

Can you think of other examples of properties of living things that can be measured and used in this way to determine differences between or within similar species?

C. Determining Conditions of Plant Growth

Collect several samples of the vines of the sweet potato. For each sample, measure the distance between successive nodes. Make a graph of the distance between nodes versus the number of the node. Each vine collected can be represented by a different line on the graph.

Do all vines show the same pattern of growth?

What pieces of information can such a graph tell us?

What explanations can you offer for the patterns of growth of the vines you have collected?

Now cut the vine across at each node and measure the cross-sectional area of the node. Make a graph of this area versus the number of the node. Again, can you offer any explanation for the relationship you have established between the size of the node and its

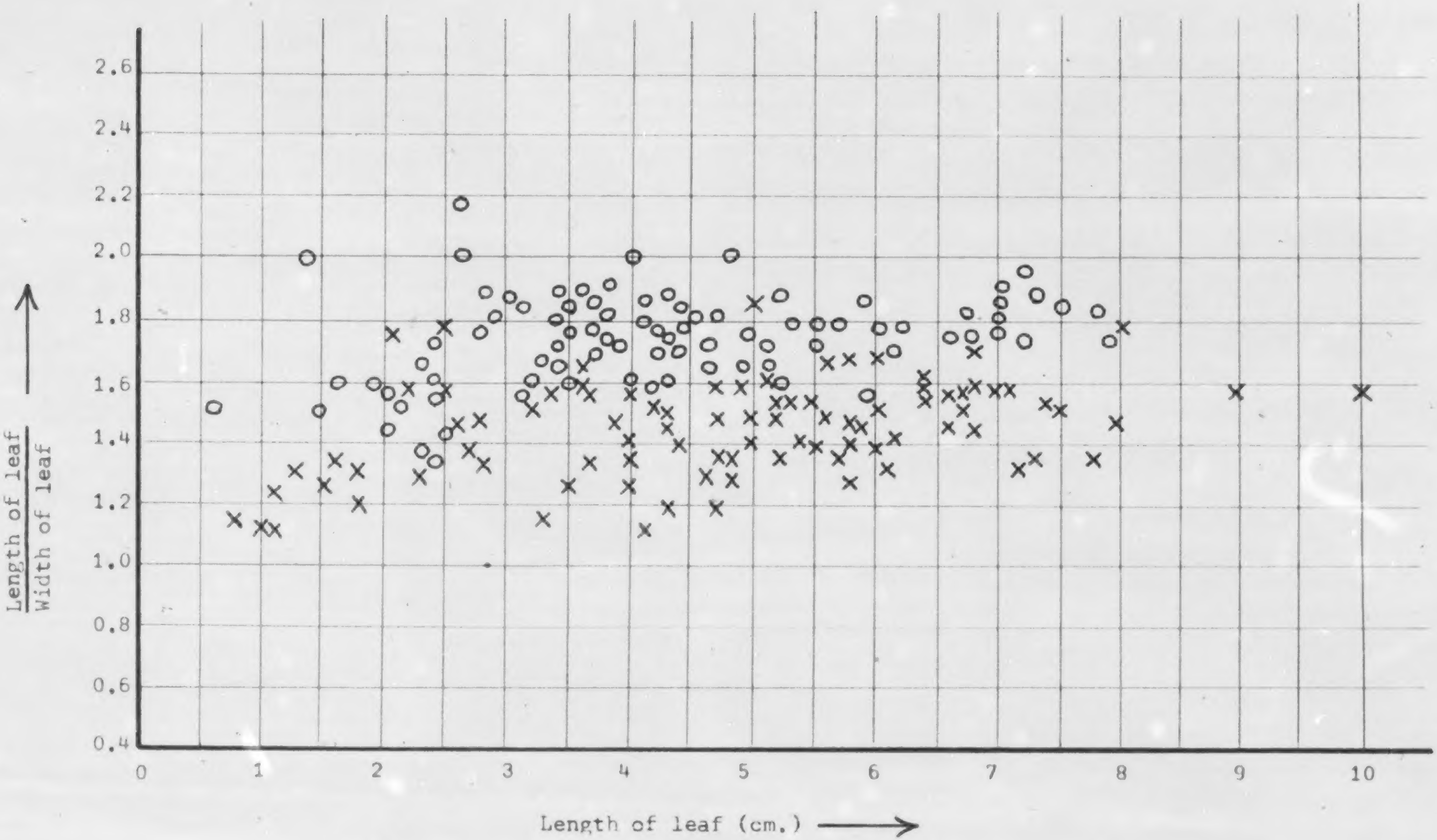


Figure 4. The shape of leaves from Bouganvillea, measured in terms of the ratio of the length of the leaf to its width, versus the length of the leaf, measured in centimetres. Points marked with (x) are from plants with pink sepals, while points marked with (o) are from plants with white sepals. Both plants grew side by side under the same conditions.

position on the vine?

This is only an example of how measurements of plants might yield information about the conditions under which they were grown. The reader is encouraged to look for and study other samples of plants and animals in a similar way.

Activity 3. Looking For Relationships

We have now seen several examples of relationships between sets of objects, or between sets of measurements. We have also seen how some of these relationships help us to learn more about the situation being studied. For example, what conclusions were you able to draw about the growth patterns of living things from the relations you established in Activity 2?

Throughout this section of the Handbook, as well as in parts of other sections, there are a variety of science investigations either described or suggested. Examine some of the areas of investigation to see if you can apply the techniques used in this chapter to identify relationships between various sets of objects or measurements.

One way in which such relationships can be useful is the following. Sometimes data collected can be used to predict the results of measurements that would be difficult or impossible to obtain. In such cases, presenting the data in the form of a graph often makes it easier to see what kind of predictions can be made. For example, in Chapter 2 of this section, Strength of Materials, there are many natural applications of the techniques of graphing.

List as many examples as you can of predictions that might be made from data that has already been collected. Where possible, carry out additional measurements to verify if your predictions are valid.

Verifying predictions that you have made is an extremely important part of the scientific process. Discrepancies between predictions and further observations force us to look for causes of such discrepancies. What discrepancies have you noticed between your predictions and observations? What do you think caused those discrepancies?

This search for causes of disagreements between theories and experiment often leads to new problems to solve. Can you think of new questions that were raised in your mind because of such disagreements? This interaction between theory and experiment is what makes the process of scientific enquiry continuous and open ended.

SECTION III

Summary

This section has shown some examples of topics for investigation by students by means of the enquiry or discovery approach. Each topic, or chapter, was described in a manner which emphasised a particular aspect of a scientific investigation. Most investigations will include some part of each of the aspects treated in the various chapters.

The reader is encouraged to look for and investigate as many different topics as possible which may be of interest. It would be useful to reflect on how each facet of a scientific investigation occurs in the studies you undertake. Experience in carrying out such scientific studies will not only add to your understanding of the world, but will also better enable you to provide opportunities for children to work in a similar fashion.

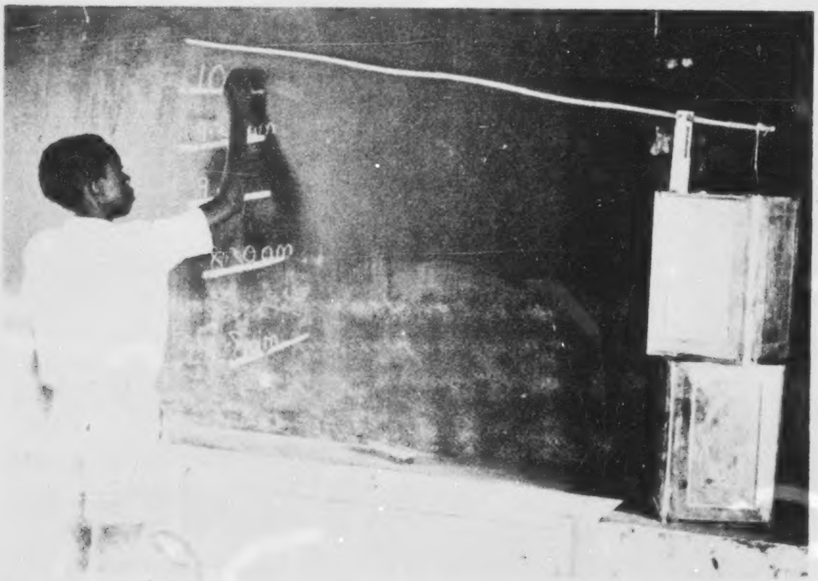
SECTION IV

ILLUSTRATIONS
OF
CHILDREN
DOING SCIENCE

LOWER PRIMARY ACTIVITIES - WET SAND

CHICKS IN THE CLASSROOM

TIME: MAKING CLOCKS



OURSELVES

FRICTION

WATER

INKS AND PAPERS

SECTION IV

ILLUSTRATIONS OF CHILDREN DOING SCIENCE

Introduction

Having engaged in some of the activities in Section III, you should be developing some ideas and feelings about what it is like to work as a scientist. Having done so, you have seen that it is exciting to do science, and that learning how to learn and to solve problems is useful. But perhaps you have begun to ask the question, "But it is difficult and can children work in this way?"

To answer this question simply by saying "Yes, of course they can," has never convinced anybody. Most people come to believe this after they have had personal experience and seen it happening with their own eyes. Starting to work with children in this style is the best way of finding out what children are capable of doing if given the opportunity. However, reading about the work that children have done, though second best, can also be exciting and educational if their work is read carefully and thoughtfully. And one must always remember, as is discussed in Section V, that children are children with their own particular way of looking at the world and that they are not miniature adults in disguise.

The readings that follow illustrate a variety of situations where children were encouraged to work as scientists (in contrast to being taught about science). Read these illustrations carefully. Then compare what the children were doing and feeling, while they are investigating, with your own experiences when you were engaged with work in Section III. Think about the value of encouraging children to work in this way.

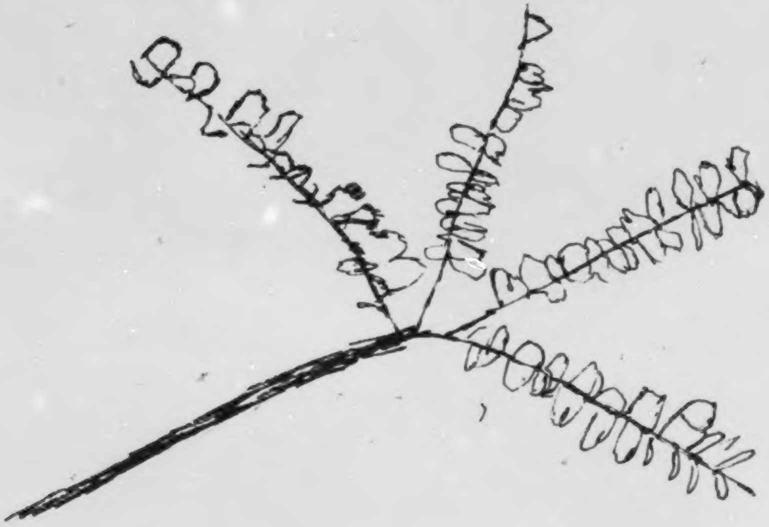
The first example is a booklet produced by a class of five and six year olds, who were stimulated to become interested in one particular plant. The second is an account written by a teacher and her class of eleven year olds who decided to explore their local environment, in this case the beach bordering the fishing village where they lived. The third is a report written by a class of eleven year olds far inland on the other side of Africa. These children, unlike the other classes, wrote their report in their mother tongue. The account in this book has been translated.

Not all the conclusions reached by the children in the third excerpt are actually valid or accurate. But they are what the children decided from their own observations. The teacher can later go back and have the pupils repeat some of their observations and re-examine their conclusions, to see if they change at all.

Obvious and gross errors can then be corrected by discussion (for the children have the background experience on which to base fruitful discussion). Alternatively, or in addition, the children can be exposed to new situations that will help them see more clearly the details they had missed, which led them to making the wrong conclusions.

This should always be recognised as part of the guidance role of the teacher. It would be otherwise self-defeating to allow children to hold inaccurate ideas or build upon inaccurate scientific information.

The Sensitive Plant



THE SENSITIVE PLANT

School : Tower Hill Kindergarten ... Sierra Leone

Teacher : Mrs. J. Hill Date : July 1972

The children (aged 5 or 6 years) came to the conclusion orally that the plant needed water to be sensitive. They thought that the reason for the plant being sensitive when its roots were in the ground, and not when the stem was planted, was that the roots could take up moisture from the soil which the stem was not able to do. However, when in water, the stem could take up water and the plant therefore remained sensitive.

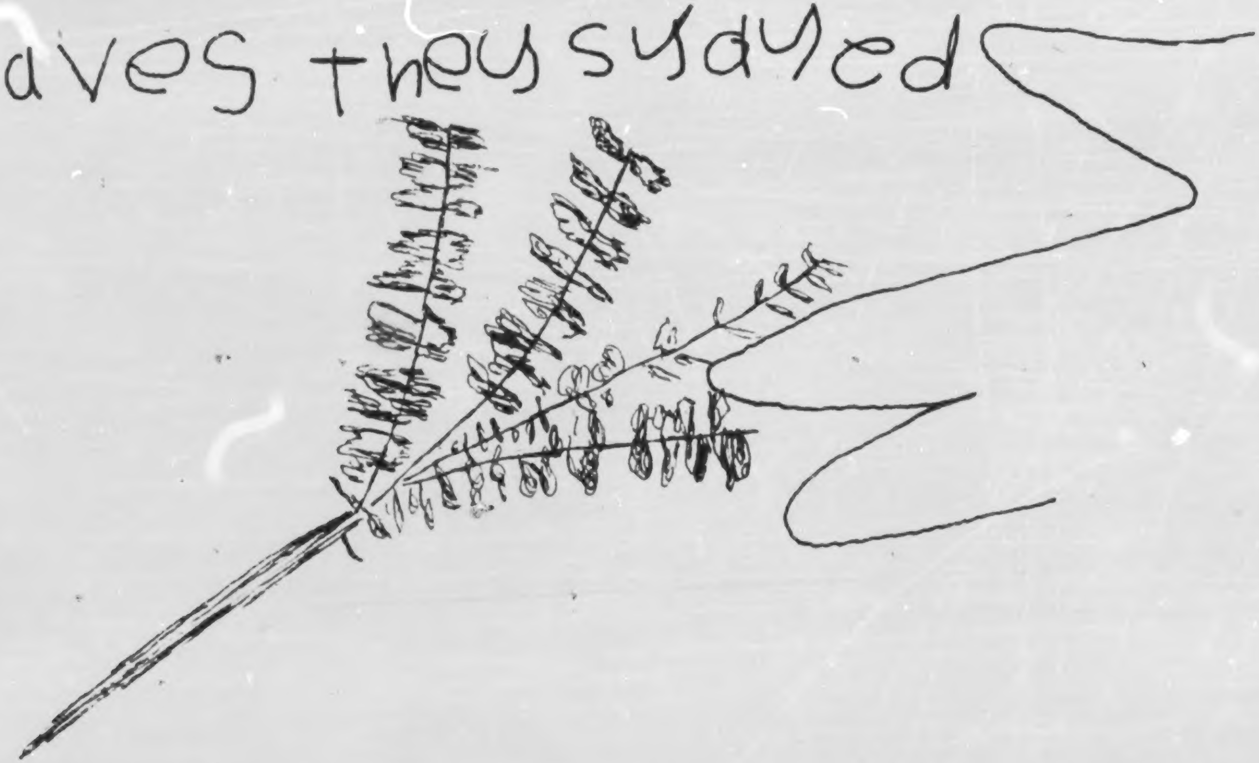
This argument was not recorded by the children because they found it difficult enough to put their conclusions into words and were not willing to spend time laboriously recording the reasoning behind each stage of the investigation.

It is interesting to note that this little investigation started with the interest of several children in the sensitive plants growing in the school playground. The teacher had absolutely no knowledge of the plant, and not until after the children had come to their conclusions did she discover that they were in fact correct in supposing that the plant needed water to display its sensitivity.

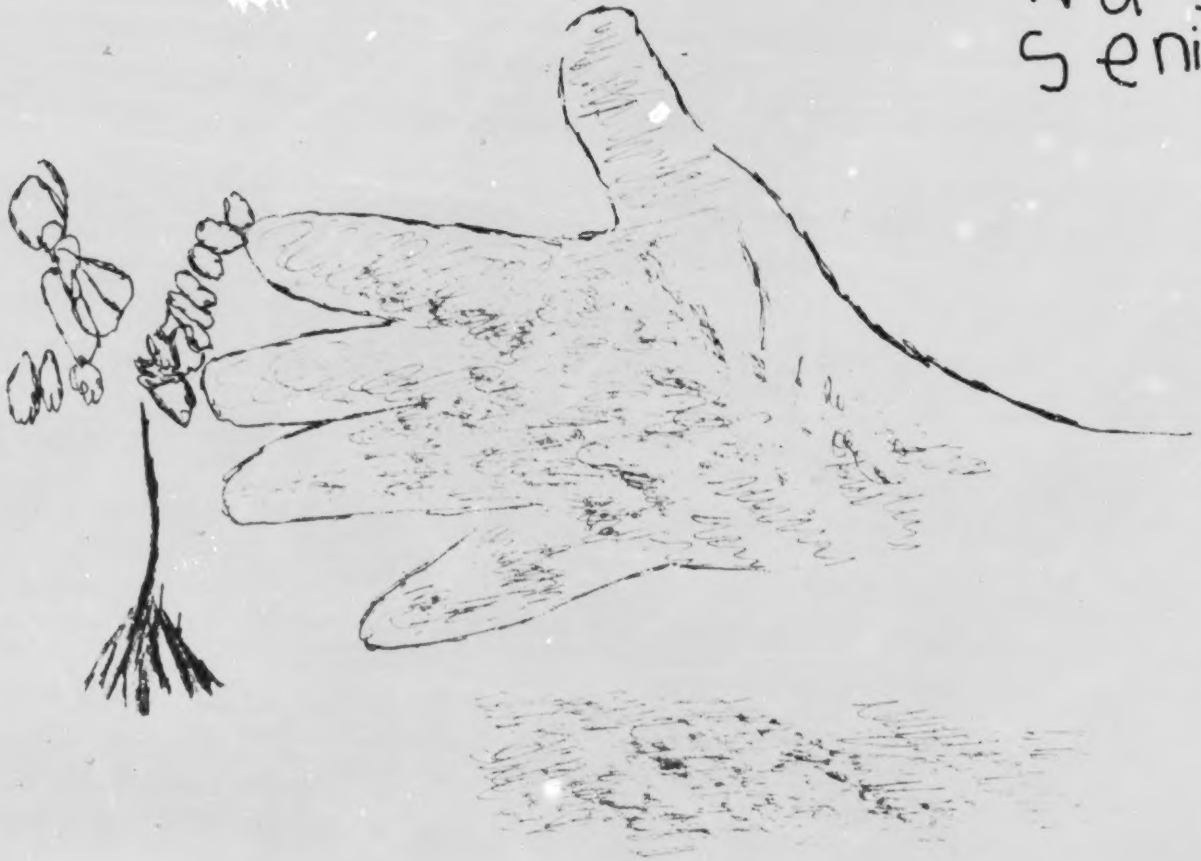
"The sensitive plant" - Mimosa pudica

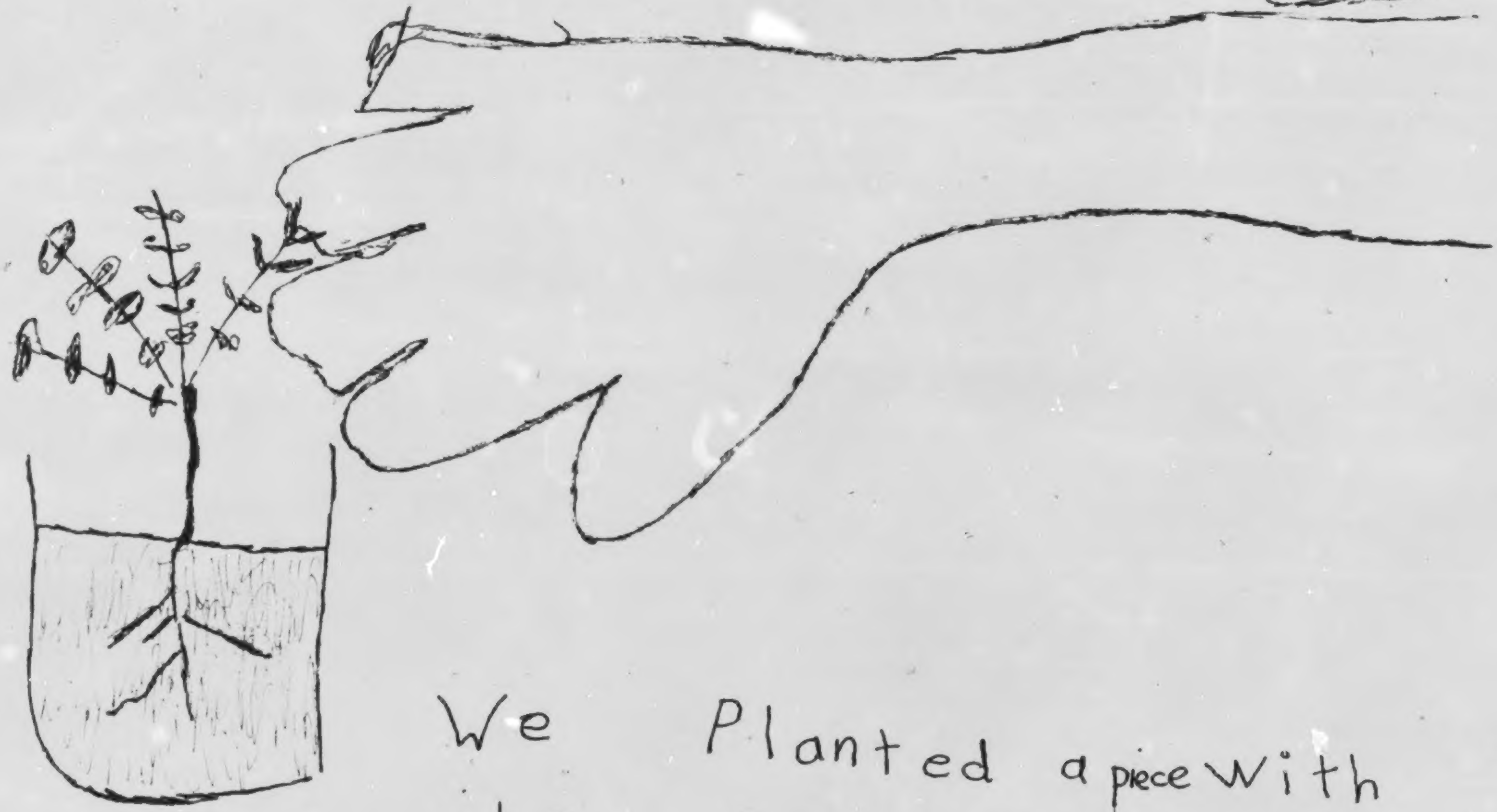
when you touchtheplant
theleavesclose

we picked a piece with
no roots when we Touched
the leaves theysydayed
open



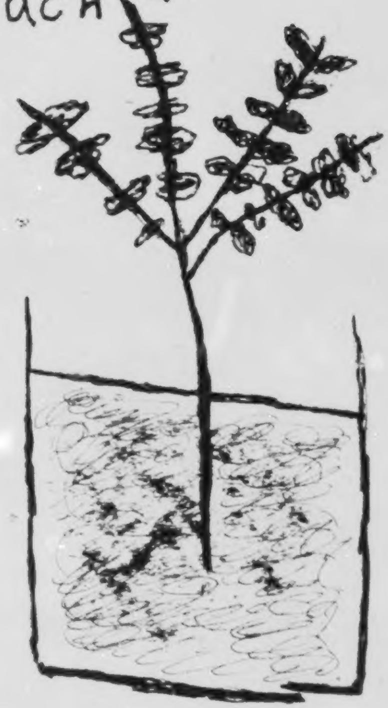
We touched a piece with roots on was not senitive

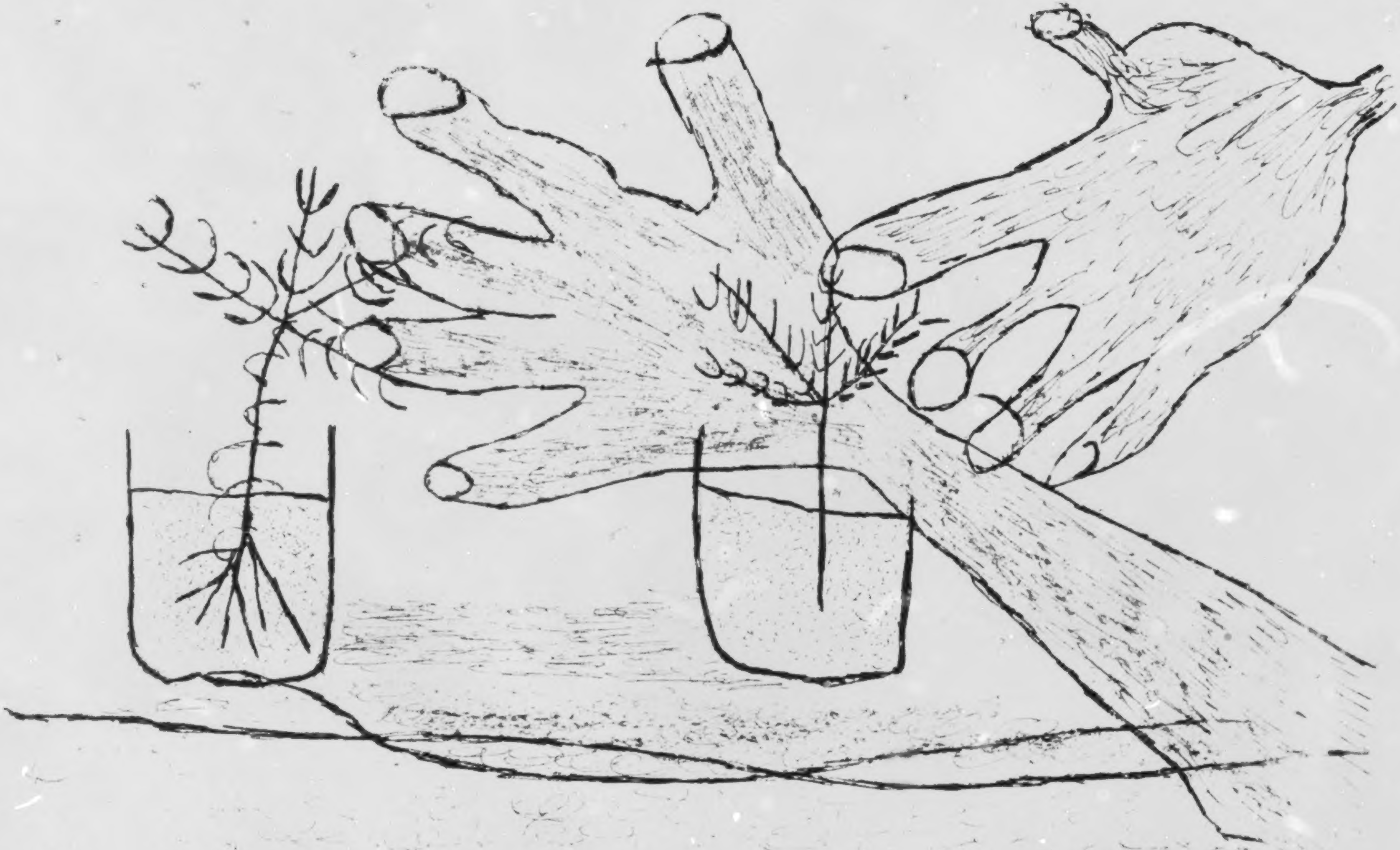




We Planted a piece With
its roots it Was
Seusitive

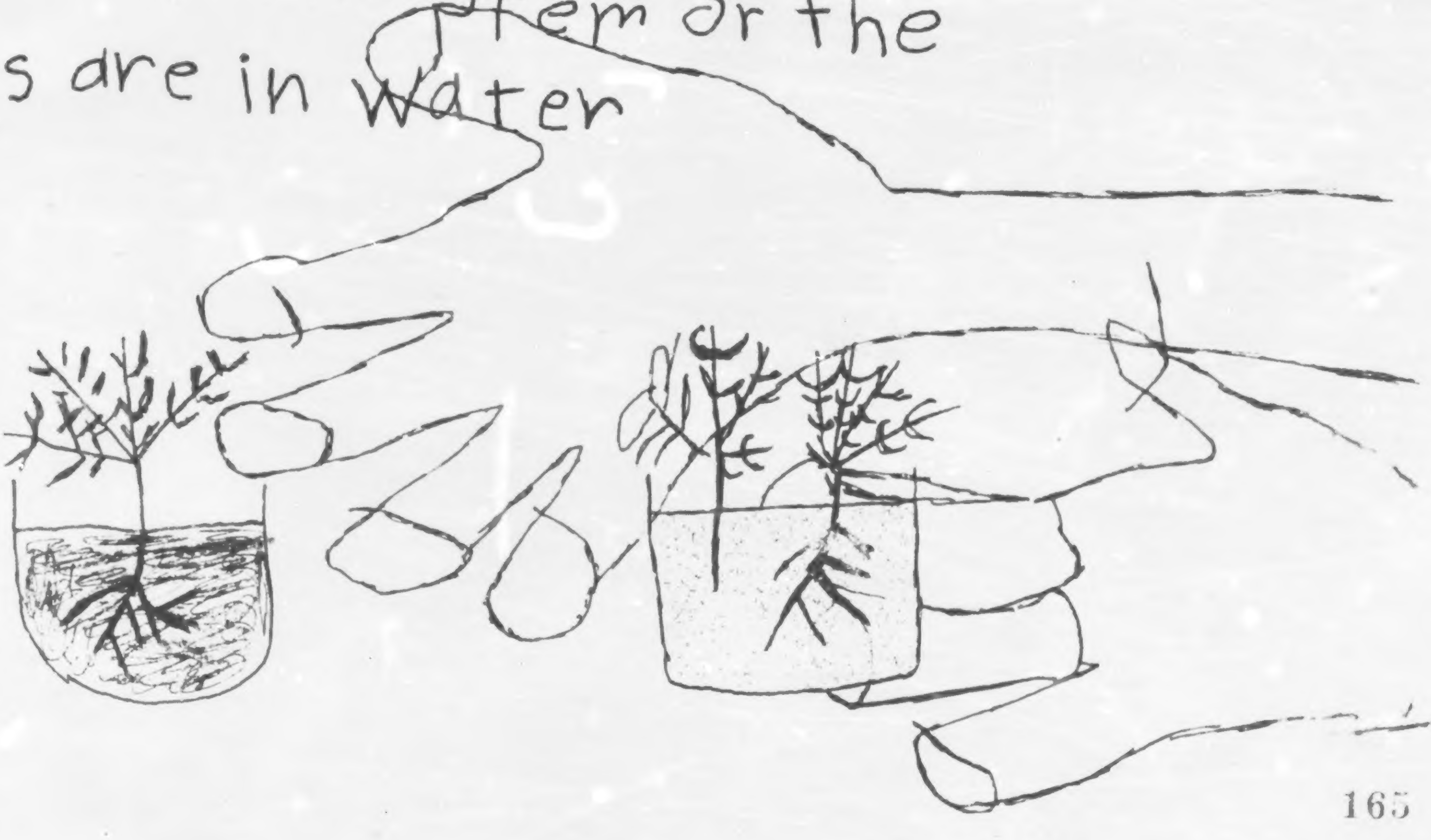
We put some leaves in the earth with no roots. When we touched them then did not close



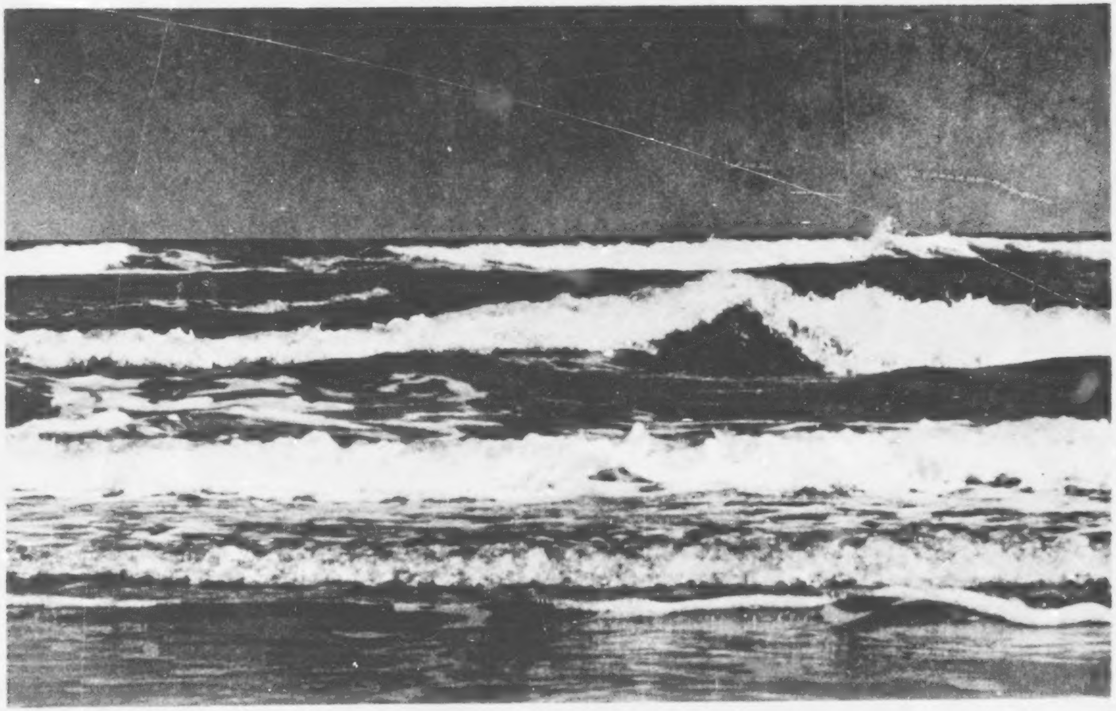


with roots or not when we put the plants
in water the leaves were sensitive

The leaves close when we touch Them when the roots are in the ground or the stem or the roots are in water



Juba Beach



A Class Record
Sierra Leone

During the months of January and February my class six children studied the beaches and sea at Juba. This book is a collection of writings, drawings and photographs of what they discovered.

As a teacher I have observed that children truly learn when they try to solve questions which they themselves ask. In order for children to ask questions they need a diversity of materials to arouse their curiousity and a sense of freedom to question and explore their own potential. For my school, the beaches provide the materials. But it doesn't matter whether it's a beach or a river or an upland farm or a village market: the children will still want to ask questions and find out. Whatever is near the school the children can study, and because it is near the school and the childrens homes it is important.

I hope the following pages show that the general topic of beaches and sea integrated many experiences of learning. The children found and observed a wide variety of animals. They examined rocks and shells and sand. They tasted and tested water for salt content. They counted waves and the flow of rivers and talked to fishermen. The challenges were without limit.

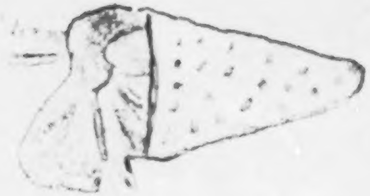
Friday.
We catch the quainde-quainde by the water side. They live in the water so they can find their food. They can keep some of the food to eat at 5p.m.

The children knew much about the beach environment before they began their study. The events of this unit encouraged them to find answers to new questions. They wanted to learn and because of this they used and developed their skills — they measured, weighed, compared and counted, they kept notes and discussed their findings. For me, their own evaluations and this record book tell more about the progress of the children than any written examination I might have given them.

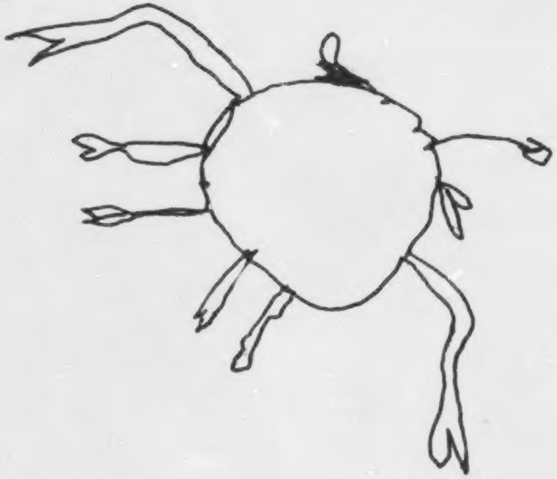
Most important, the children had the satisfaction of discovering things on their own. Their discoveries built their confidence to look further into what is around them. This book is the result of the children's looking and experimenting, a continuous inquiry into their environment.

Hawa I. Kamara

Teacher
Juba Army Rural School.



This is the quainde-quainde I caught.
It looks like a snails house.



We find the beach
Crabs on the Sand.
When they see people they
run into their holes.
when you go away they came out.
They are very Sensible.
When I caught a crab my teacher came to help me.
I was so happy because it was the only catch in
our group.

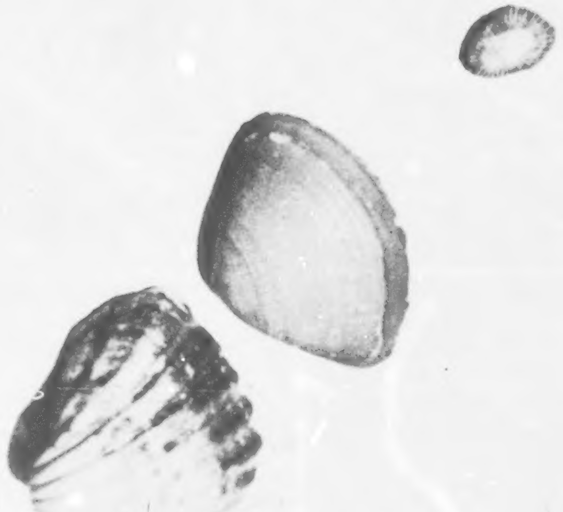
when I dig the sand
there is water comingup.
The water tastes
Salty

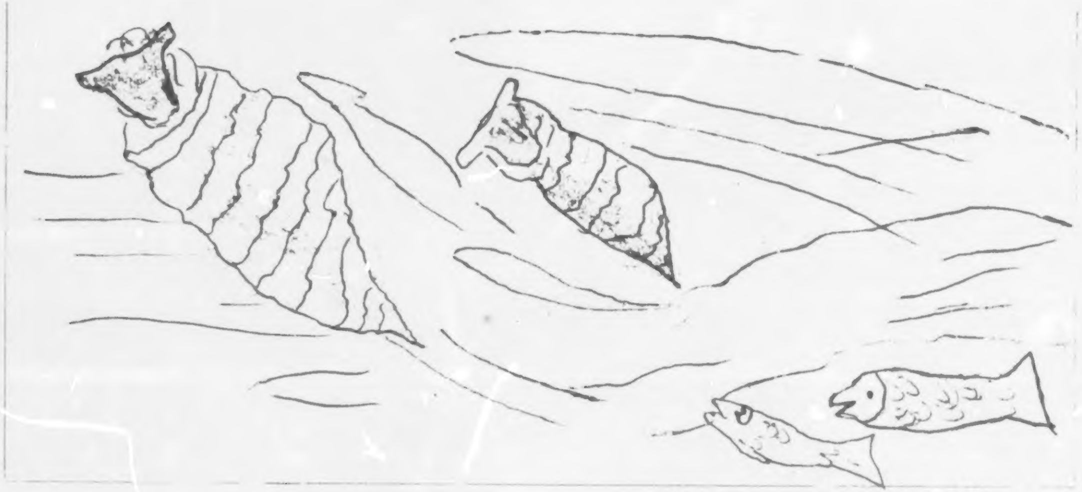
There are Shells on The Sand and in the water and big ants on the Sand.

There are Seaweeds and little bits of leaVES which have change colour

when the waves work on the sand the Sand falls down into the Sea wednesday

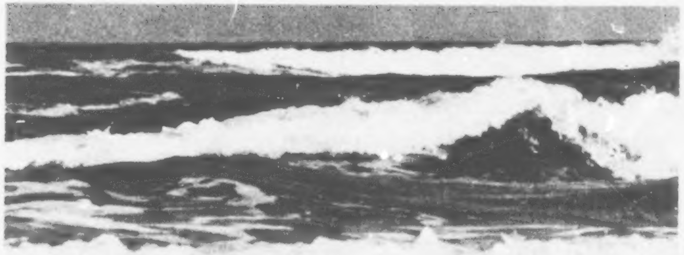
There are so many shells on the beach. Some are big and Some are Small and Some are little and they have different colours, brown red yellow gray and white Some of the Shells are like Stone and Some are like fingernails and Some I can put in my house.





Shell

The water makes noise
when the waves come.
It gets mixed up and
gives white form.

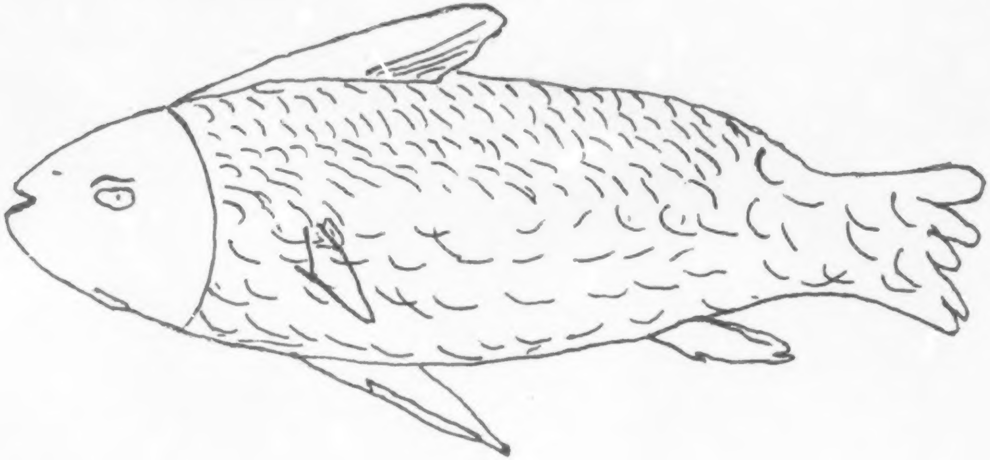


Osman took the middle of a banana tree and then threw it in the water.
Then the water and the waves took the stick away.

The colour of the rocks is brown and dark. Some of the rocks are on top of others. I can see so many holes in the rocks, and in the holes I can see small crabs/. and cockles and I can see the rocks shining.

Thursday, 14th January 1971.

When we made groups we went down to the beach by Lumley Creek. Then we started collecting things we found on the beach. First we collected fishes then we collected crabs and snails. When We were collecting crabs then Roy went for his line so that he will catch other fishes. There were oysters and shells on the rocks. There were many rocks in the beach.

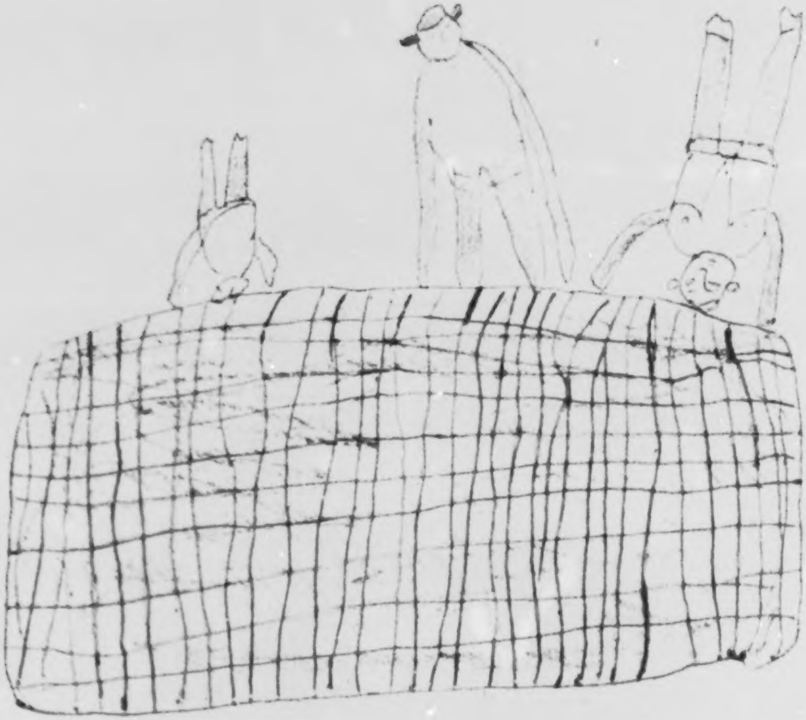


The fish is called Mango Page. We
Find the fish in the water
under the stones and put net there
and catch the fish in the net. It
has mouth, tail body and scales
and nose and eyes.

After a week of working with the children a spirit of zeal and happiness came over me. By this time I saw that the children, when left to themselves, can learn many things. They no longer waited for me to give them instructions. Instead each group of four chose a leader and the children kept daily records of what they did.

At this stage the children started making investigations even after school hours. They often reported their findings in class the following day.

Daily the children became more curious about the environment of the beach. And daily my interest became greater as I saw how the children were progressing. Soon the children started looking more closely at tides and waves, water and sand, the river and many other things.

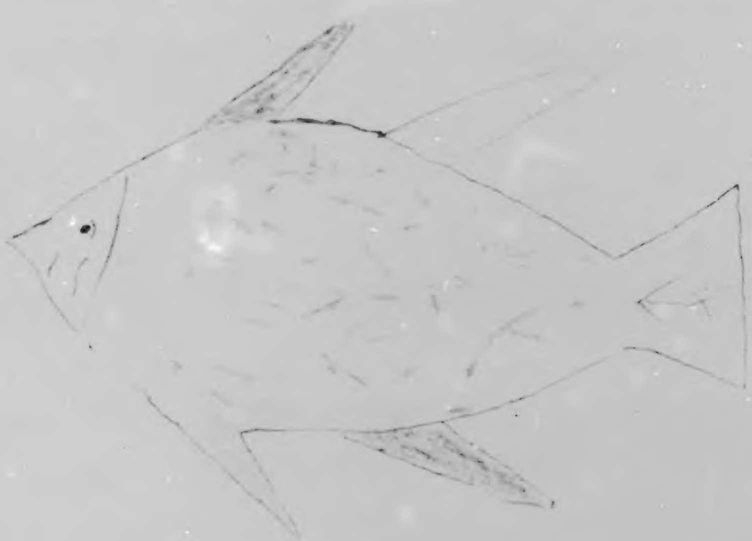


Before the fishermen go to the sea they first arrange their boat and net and Paddles. Then they sit in the boat and they start to paddle. When they reach the middle of the sea they drive the fish into the net. Some people draw the net to the beach. They catch many fish from the sea.

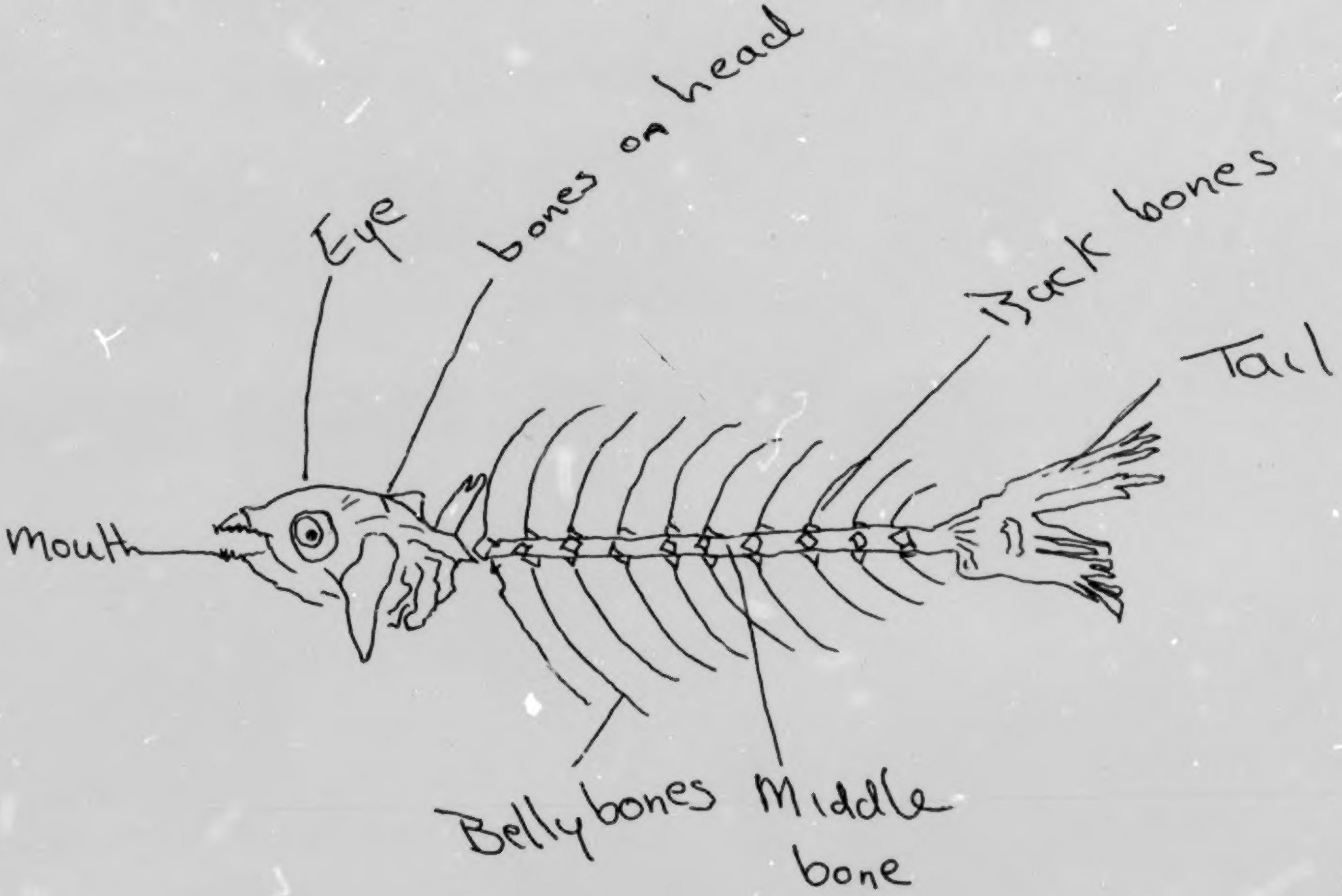
194

194-A

We caught fishes on Thursday. We put salt water in Calabash and jars and put the fishe there. On Friday the fish were dead. The water has changed to light brown. The fish died because the water in the sea is not like the water we put them in. This water is hot and the one in the Sea was cold The body of the fishes were soft and hot when they died. About the fish we have. different kinds of fish, big fish small fish and fish with Scales and fish with no scales. The crocus and the sole fish have tails. The eyes of the sole fish were black and white. The Crocus gill is different from the butterfish. The butterfish mouth was long. They have many bones inside their body.

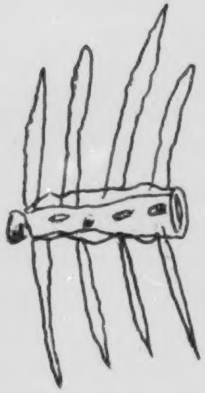


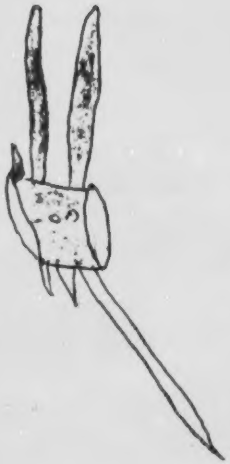
A fish has no Neck

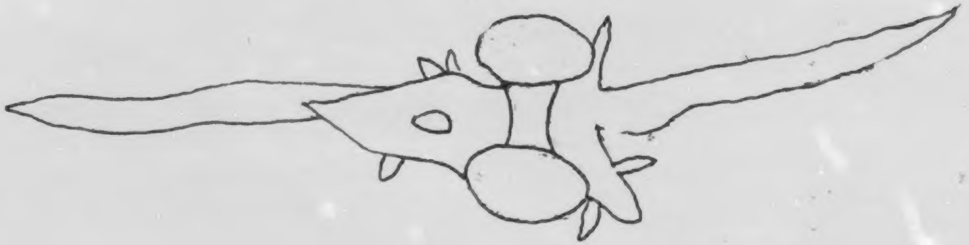

Eye
bones on head
Back bones
Tail
Mouth
Bellybones
Middle bone

We boiled 3 fishes for 10minutes.When they got cold we pulled the flesh.

ihe bones we get from the fishes are not like the ones we get from the dog or cats or rats or my animal.







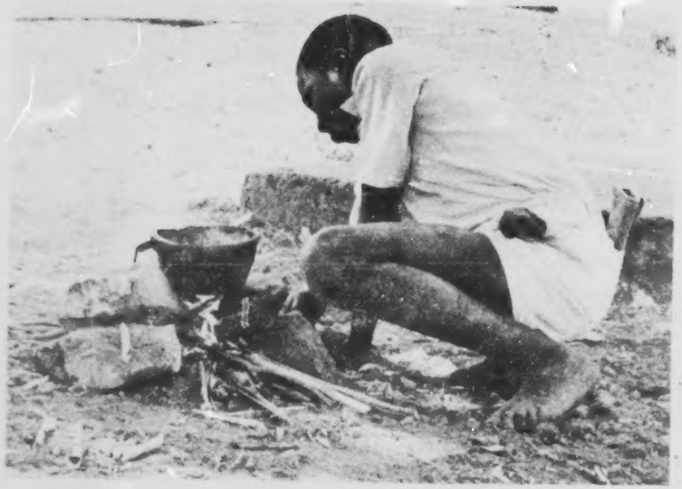
I tried to ask questions which would lead the children to further inquiry. As the children went on, new questions started coming from what they were studying and from each other rather than from me.

Here are some of the questions:

What do the waves bring to the beach?
How does sand move along the beach?
Why does dry sand stick to my feet?
Why is wet sand heavier than dry sand?
How far do you have to dig in the sand to find water?
How does a crab dig a hole in the sand?
Why are some crab holes very big and some very small?
How close can you get to a crab before it runs away?
How many legs does a crab have?
What do crabs do at night?
Can fresh water fish live in salt water?
Can salt water fish live in fresh water?
What can you use to feed fish in the classroom?
What keeps the fish's bones together?
Do all butterfish have 21 bones?
How does a fish move in water?
Why can't we live like fish?
What makes quainde-quainde stick on rocks?
Where does the water go at low tide?
Is the tide high in Juba at the same time as in Kissy?
Do waves make noise in the middle of the ocean?
Why couldn't we make the fresh water foam?
How much salt is in a gallon of sea water?

Tuesday 7th February

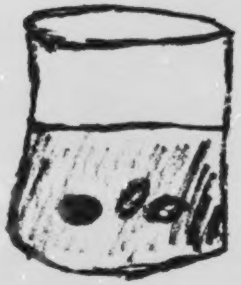
Amadu and I took salt water and put it in the tin over a fire. Before the water started to boil we can see the bubbles of the water come out of the pot and then the water started to boil.



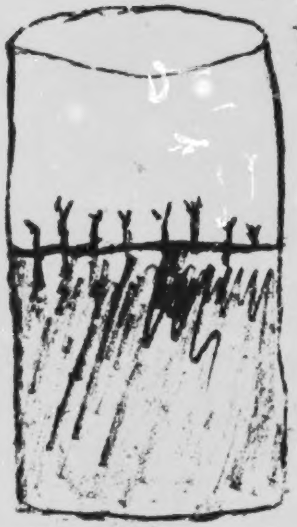
We can't see the salt inside the pot until the water was drying. When it started to dry it looked like oil. The colour of the salt is brown. The salt we made is not the same as the salt in the house. The salt in the house is white. The place that we took the water is from the sea by Juba beach.

On friday We put Soil in two Cups. We Put fresh Woter in one and Salt Water in one. Then We Planted our lettuce Seeds in the Cups. On Monday After lunchtime I See What it has done. The one in the Soil and fresh Water has grown and the One in the Soil and Salt Water has not grown.

Today our group Planted other Seeds to See if they can grow in empty Water Without Soil in it. And we Plant one With Salt Water and the other one With fresh Water. Today is Wednesday and I Want to Know if it Will grow on Friday.



The salt Water and the Little Seeds.



The Lettuce in the fresh Water Has all Grown in the jar.

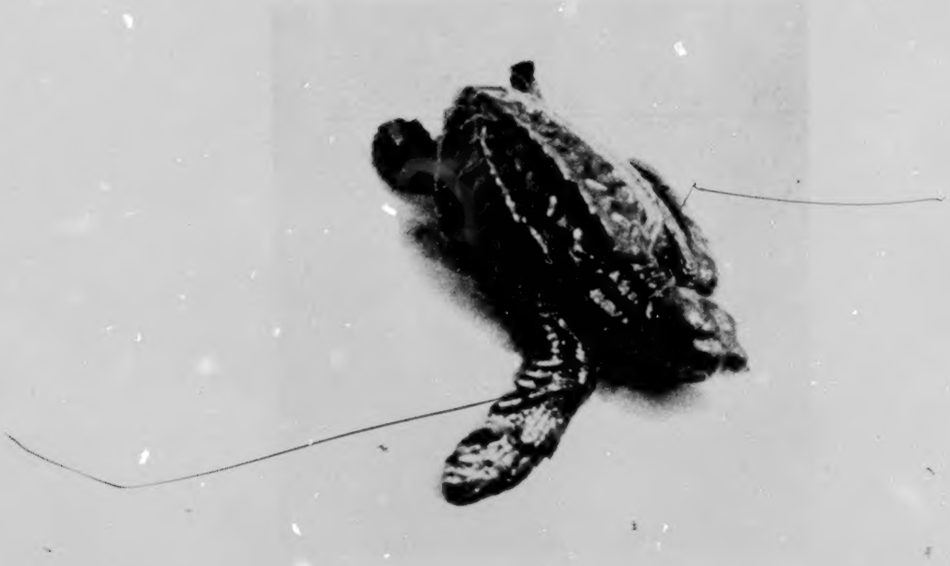
Friday 9th February, 1971 Mamah Conteh

Soil and fresh Water.	Soil and Salt Water	fresh Water	Salt Water.
1) When I Put the Water in the Loam Soil I See bubbles coming 2) The Seeds take one day to germinat	1) The Seeds in the Soil and Salt Water have not germinated	1) The Lettuce changed colour into green yesterday. 2) The Seeds in fresh Water has got one leaf. 3) The one in fresh Water grew first	1) The one in The Salt Water hasnt grown yet because the Salt water Makes it not to grow

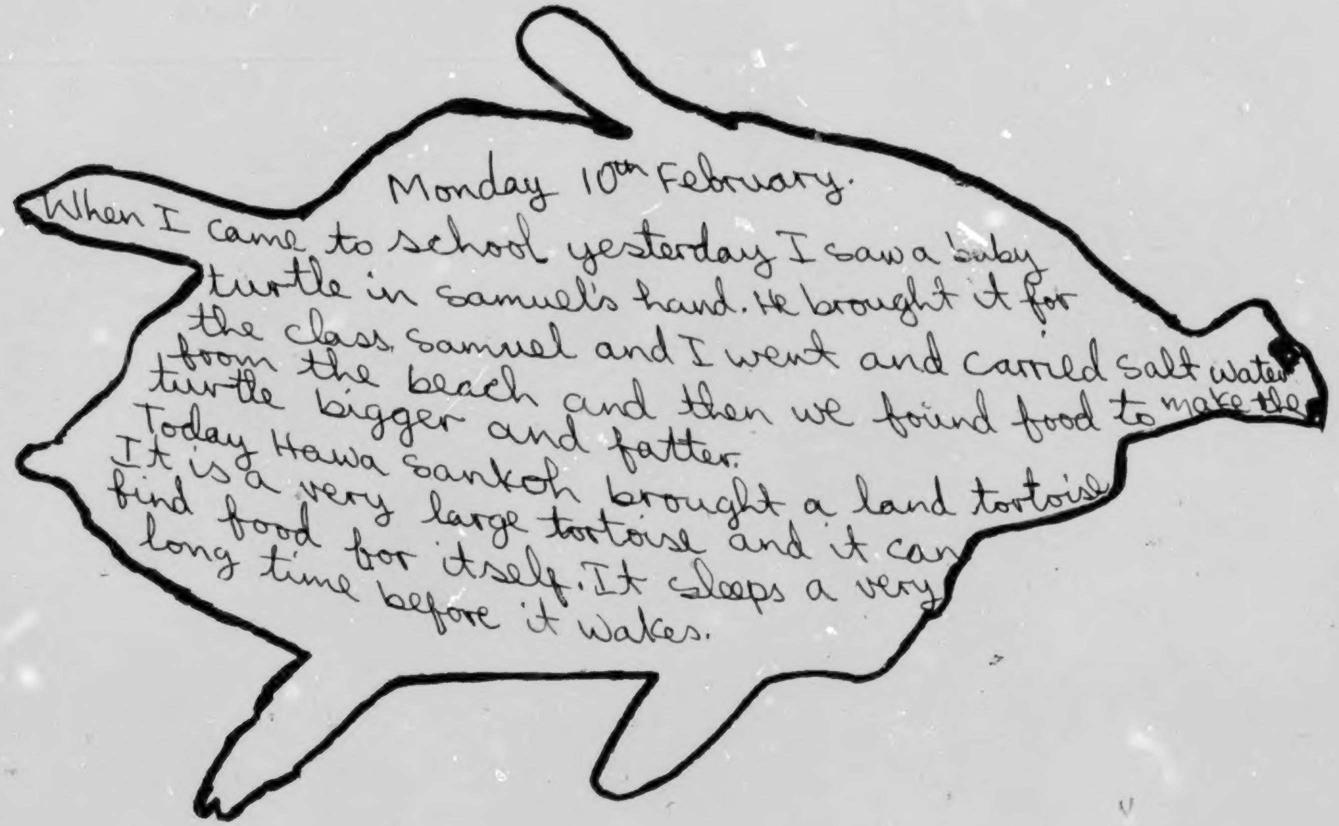
Near our school we have a fresh-water swamp named Portoh Swamp which has an outlet to the sea. The children told me that they find many animals in this swamp — needlefishes, mudskippers, crabs and tortoises.

The day after Samuel came to school with a baby sea turtle, Hawa found a land tortoise. I saw this as an opportunity for the children to compare animals from different environments. We talked about the animals we had already collected and the places we had collected them. Soon after, I took the class to Portoh Swamp.

Some of the animals the children found at the swamp were quite different from animals that live near the beach. I learned that the sea hare and mudskipper are animals only found in swampy or tidal waters. Others, such as the land tortoise and land crab, look like their neighbors the sea turtle and beach crab, but the children gradually discovered that animals which look alike may be very different.



This turtle is the sea turtle and it has got hands like a leaf. It is a young turtle The fishermen told us it can live far hundreds of years.

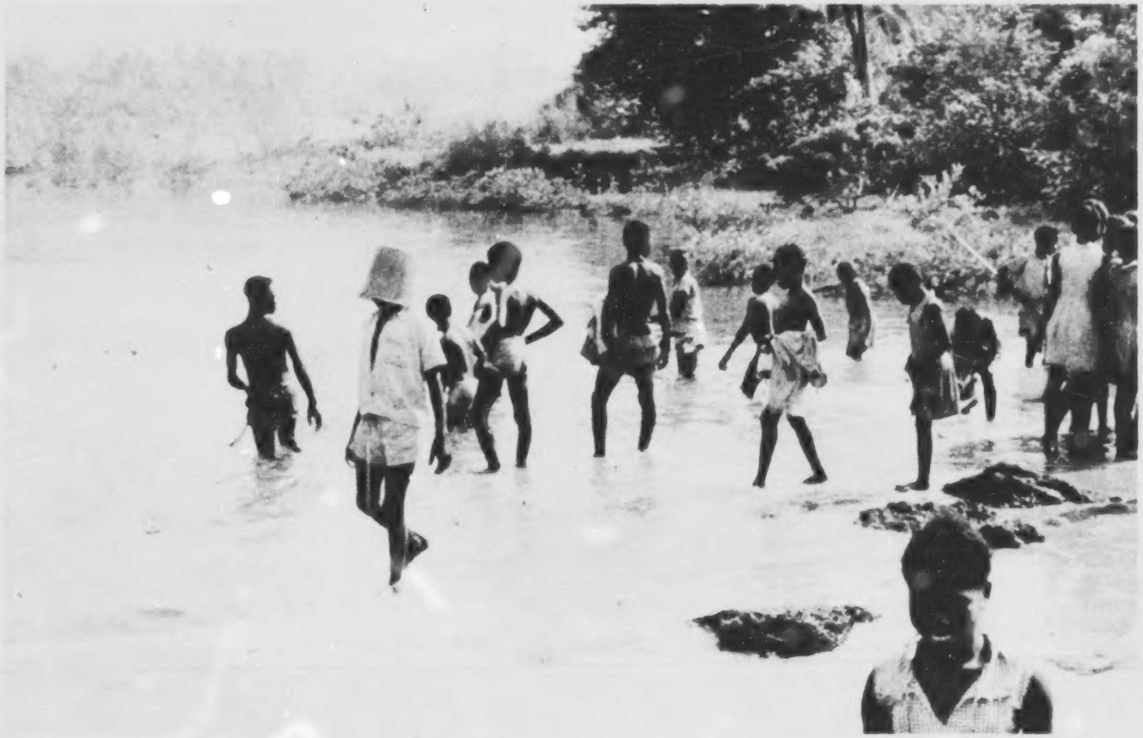


Monday 10th February.

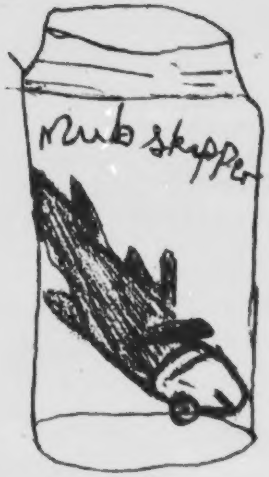
When I came to school yesterday I saw a baby turtle in samuel's hand. He brought it for the class. samuel and I went and carried salt water from the beach and then we found food to make the turtle bigger and fatter.

Today Hawa sankoh brought a land tortoise. It is a very large tortoise and it can find food for itself. It sleeps a very long time before it wakes.

Tuesday.
We went to Portoh swamp today. The water is mixed with soil and sand and there are a lot of trees and a small river. Sometimes when it is high tide the salt water runs through the river and becomes mixed with fresh water. Sometimes when the water is full the fishes in the sea come with the water to the little river.



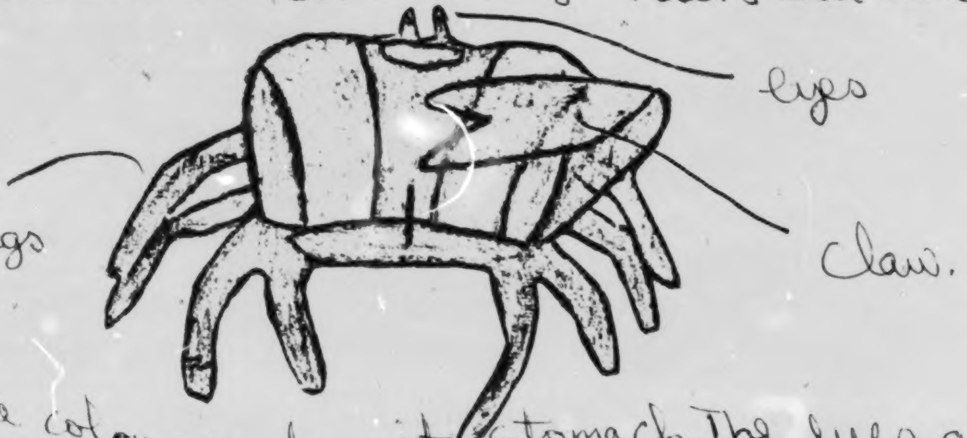
We catch the mudskipper around the rocks. It is not swimming like the fishes, It is jumping in the water. It's skin is smooth because it hasn't any Scale. It's tail is like a fish but it's head is not like a fish's head, the eyes are on top. It eats worms and any other thing. It is alive when we catch it, but now it is dead.



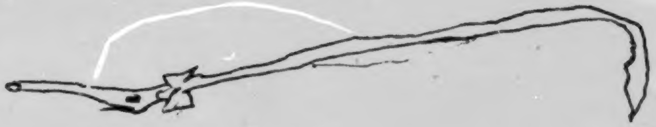
The crab which lives in the water is different from
same. The crab which lives on the land is all over
which lives in the sea has a brown colour on its
not the same. The crab in the sea has big eyes and
crab which lives on the land people do not eat it
in the sea people all like to eat it because it is

Note - These two pages are meant to be read across the two pages. First line on this page goes on to first line on following page, etc.

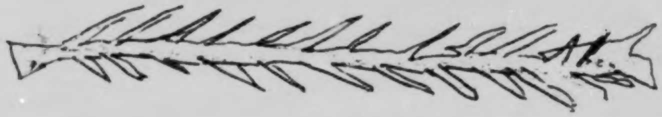
the one which lives on the land. The colours are not the
red and on his skin it has so many hairs but the crab

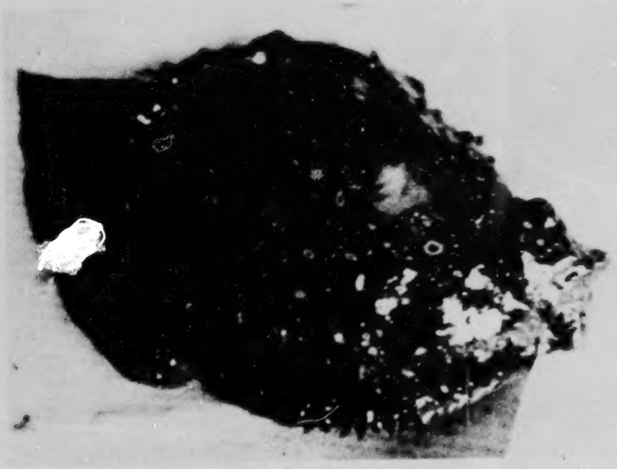


back and white colour under its stomach. The eyes are
the Crab which lives on the land has small eyes. The
because it is not good to eat but the crab which lives
very good to eat.

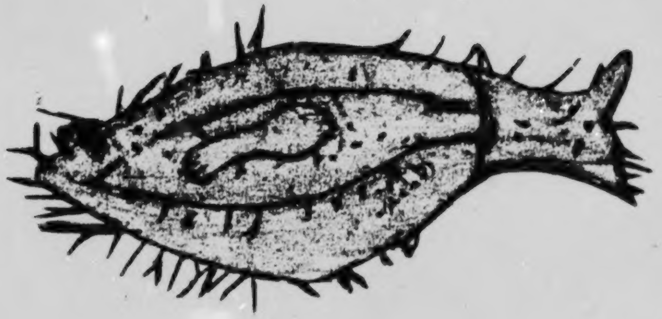


on the first day when we collected the needle fishes they were moving about and their Skin was fresh. When I Squeezed one it pulled water out of its Skin. It had a thin body and long mouth. When we bought the needlefishes we left them in a jar of water. The next day we Started putting Spirit on them so that they will die.





There was surprise and excitement among all the children when one group which had moved to the far end of the river brought back a strange animal. None of us had seen it before. The children wanted to know the name of this animal. We hurried to our headmistress Mrs. Finney. But she herself was seeing it for the first time too. At her suggestion we carried the specimens to Mrs. Gomez, Inspector of Schools. Mrs. Gomez sent the animals to Drs. Norman Cole and Modupe Williams of the University of Sierra Leone. Four days later we heard with great pride that this was the first time so many of these animals had been seen in the University laboratories. We learned that the animal was called the sea hare, or aplysia. The children were happy that they had discovered something of help to the University.



The name of the animal is the Sea hare. The Sea hare has a very little mouth. When we touch the Sea hare it opens its back and gives a mauve colour like ink. I think that when fishes want to eat the Sea hare it uses the colour to blind them.

It Killed a Crab.

If you feel the Sea hare it's like Silk. Its colours are blue, brown, black and mauve. It has two horns and many hairs on its body. When Allie placed it on the dry Paper it does not move but when he put it on the wet Paper it moves. The Sea hare Slides like a Snail but it doesn't have a Shell.

FOURAH BAY COLLEGE

Department of Zoology,

FREETOWN
SIERRA LEONE

REFERENCE

Miss Hawa Kamara,
Juba Army Rural Primary School
Juba.

20 February 1971

Dear Miss Kamara,

I received a collection of sea hares brought to the Department for identification by Mrs. I.D.Gomes, Inspector of Schools. I understand that they were collected by pupils of class six, under your direction. This is the largest local collection of Aplysia, the sea hare that I have ever seen. We had previously collected only one specimen at York beach a few years ago.

Your pupils ought to be encouraged on the collection and study of animals not only from the sea-shore but also from other habitats, as this is the best way of learning about living things.

We would always be willing to help in the identification of animals and render any other form of assistance in your study of the Fauna of Sierra Leone.

I wish you success in your undertaking.

Yours sincerely,

M.O.Williams
Professor & Head of Department.

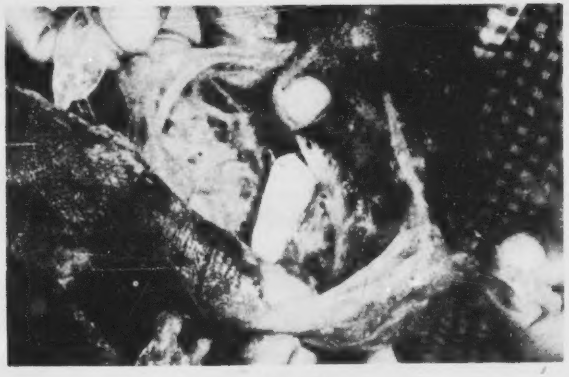
One afternoon the children and I went down the beach to study the habitat of the sea hare and to make further collections of fishes and crabs. We left the river and were moving towards the swamp end when suddenly a shout came from one of the boys in front. "Teacher, there is a big crocodile under the mangrove plants!" We were so panicked that we ran immediately from the swamp end of the river to the beach.

I was curious to know about crocodiles. I started to question the children. First I found out that this crocodile seen in the river was dead. I asked what would have happened to us if it were alive. One child said that it would have torn us to pieces, another that it would have thrown us in the river with its tail.

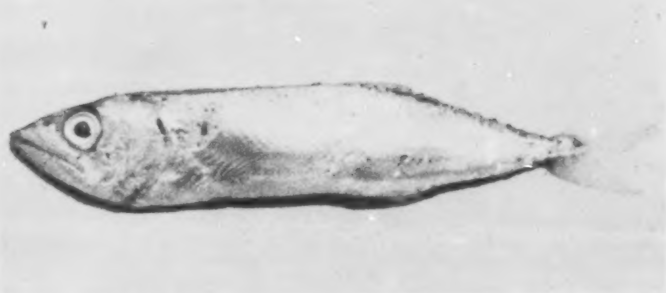
At this time I learned from the children that there are many crocodiles in the river. Sometimes they even approach nearby houses. The fishermen hunt them. We took part of the decomposed skin, examined it and threw it in the water. If the crocodile had not been so badly decomposed we would have taken the bones to class for our collections.

It wasn't everyday that the children set out for the beach with definite objectives. Even when they did plan activities there was always time to pursue the unexpected occurrence. That is what happened with the crocodile and the sea hare.

Sometimes the children just built little grass houses in the sand, or made drip castles, or talked to people on the beach, or searched for things the waves had washed ashore.



This jelly-
fish eat fishes



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UNAWAJUA? (Do You Know Them?)

Introduction

The topic on Insects is perhaps the longest ever done by pupils of Standard V. On the other hand, it was a very interesting one as far as their participation is concerned. I am therefore apt to think that this has been so first, because of the natural interest of children to play with things, and especially living creatures like insects which they can run after, catch, keep and sometimes even eat just as a matter of play.

Secondly, maybe it's because they can be seen almost everywhere, and so it is not much trouble to get them. Thirdly, insects, especially some of them, are very beautiful and so they're very attractive in their construction. Lastly, but not really the least, some children are a bit interested in finding out more about these "dudus."

Having done the topic on "Seeds," it was the children who suggested to me this topic on insects. I didn't object but instead allowed them to go ahead.

They began studying various insects which are mostly found in the area around the school. One group, for example, would go to catch one or two insects according to the group's decision. What they did after that was to observe the outside structure of the insect(s) closely using their first hand tools, the eyes, hands and when necessary they did use hand lenses. After that they'd meet and examine the insects more carefully before they went back into the classroom to write down short notes of at least the main things to remember.

The following day they'd catch some other insects of the same type and follow their whereabouts. Once they had had enough information they either left the particular insects like that or caught at least one and kept him somewhere in the tin or pinned him on the wall as a sample. Some pupils having caught and examined them, drew a picture of them and then left them to go their way.

Their procedure of examining them was as follows: their construction, the number of legs, the colour, whether flying or jumping insects, where to find them mostly, and their food. Of course, each group had its own way of investigation though in actual fact, the principles were more or less the same. This went on in accordance with group preferences and wishes in the areas of study.

"Which insects resemble each other and in which way?" This and many other questions put some children in the activities of comparing one insect to another while some pupils had already been doing it without help. This could be seen in their science notebooks. Here, their short previous notes proved that they were very useful because in order to put the various insects into classes they had forgotten or wanted to prove or make sure of, they had to refer to their notebooks.

After this work of classification each group continued with the study on the insects it was most interested in. This was just my own suggestion, for some groups, one or two, which hadn't really shown great interest in any of the "dudus" they had observed. Most groups had already, at this stage, been involved in finding out more about their particular insect. Two groups were busy with spiders (Buibui) one with grasshoppers "Panzi," and another one with "9 Desemba" and the last one with a butterfly "Kipopoo." In the long run, the four groups changed their minds and decided to learn about the spider. (One reason they gave was that they couldn't get enough information because it was difficult to get the eggs of the other three animals.) "What makes you choose a spider?" Well sir, it's very easily found, it's not very fierce, it's beautiful, its way of catching insects is very funny, we like it and many other reasons. These were the reasons most pupils gave me. They went ahead finding out and writing notes down and others making drawings, until they discovered surprisingly enough that there were about five types of spiders just around the school.

We then had a discussion about what we had been learning and what we could do with the ideas and facts we had gathered. There were many suggestions but the suggestion most welcomed by the majority was that of making or keeping our work of research in some good order in the form of a book. It was suggested that a committee of six trusted pupils to work together with the teacher be elected. Its duty would be to collect the materials from different individual and group notes and arrange them orderly in a single book. Therefore, six pupils were elected and they began their work seriously. They did this for almost a fortnight and were just going to complete the first rough copy when they had to break off. I took the trouble myself to complete the left-out bit and then rewrite it more neatly after I had made a few corrections here and there, mostly being in language.

It should be understood that the insects which are in their writing are not the only ones they've studied about. No, these are just some of the many.

According to the children's response, their participation and reports they have given, I should say that at least a good number of them have learnt at least one of the following things, if not more:

a. That the method of approach of finding out about something is the way of questioning leading to tackling of ordinary problems logically, and not just accepting an answer or idea before proving or making sure by doing and giving reasons why!

b. That cooperation is sometimes necessary.

c. Writing down clear notes is very helpful, especially when one has to refer back to them. On the whole there is some improvement as to the way notes are now jotted down.

d. Discovered the secrets of some of the "dudus" they know very little about or were very much afraid of or heard strange and false stories about. They learnt, too, that after all, not all insects are harmful and useless, but actually most of the harmful insects are on the one hand harmful to some extent, but on the other hand very useful in other ways.

Conrad J. Bugeke
New Science Teacher
Kigurunyembe Primary School
Tanzania

DO YOU KNOW THEM?

The committee of pupils from the Standard V class of Kigurunyembe Demonstration School which concerned itself with the collection of various information and with preparing this document was comprised of:

Jume Kibwana
Brigitha Nicolas
Joel Mwangulumba
Maria John
Hamisi Salum
Celestin Francis

Advisory Teacher: C.J. Bugeke

We welcome any suggestions from you regarding any changes or additions which may be considered necessary.

ARTHROPODA - Insects

Insects, which are living beings like men, differ in form, how they live and the foods they eat.

There are very many kinds of insects in the world in the same way as there are many different tribes or nations who live differently.

The following are but a few of the insects we have carefully observed and interested outselves very much in the manner of their creation and living. We have thus thought it important to put them in writing as memorandum because from their study we have learnt a lot of useful information and we hope we shall continue to learn a lot more.

Standard V
Kigurunyembe Demonstration School

INSECTS WHICH LIVE COMMUNALLY

Londoza (Wasp), Mchwa (White Ant), Nyenyele (Small Black Ant),
Nyuki (Bee), Siafu (Safari Ant), Sungusungu (Large Black Ant)

Nyenyele

Nyenyele is one of the very smallest insects but cunning in its way of life. This insect and its kind live in the soil but it also likes climbing on such trees as mango-trees when searching for anything for himself.

Many of these insects live together, helping each other in finding food, building houses and in protecting themselves against their enemies and rain. You can hardly see them single because they are so small and must be many to help each other to be able to do the more difficult tasks. An interesting thing about them is that they do not rest throughout the day except at night only.

We have tried to put a different insect in their hole. Alas! It is exciting how they all attack the grasshopper. They do not leave him alone until he is dead and there and then they will have found their food. We have discovered that during the rainy season water does not get to them because in their hole there are very many rooms and a lot of corners. Their food is other smaller insects and powdery things because we have seen them discharge remains of insects like white ants.

The other insects mentioned above live together like Nyenyele.

INSECTS WHICH MAKE HONEY

Bee, Butterfly, Wasp

Bee*

The bee lays its eggs and puts them in her house in different rooms. When the young ones come out she busies herself looking for food for them from flowers or fruits. They grow until they are quite big then they develop eyes and in their bellies there is white milk which helps them as food also.

The bee carries its food by sucking it and also uses its legs because they are hairy for catching things. In its rooms it keeps the sweet watery substance and other things which make honey. After a certain long period the honey goes bad.

INSECTS WHICH DO NOT BITE

Chambo (Earth-worm), Mndewa (?) 9 - Desemba (Praying Mantis),

Sia (Leaping insects), Kipepec (Butterfly), Fukufuku (Ant-lion)

9-Desemba

This is one of the humblest insects which does not bite and hurt. This insect is really wonderful but belongs to the grasshopper family.

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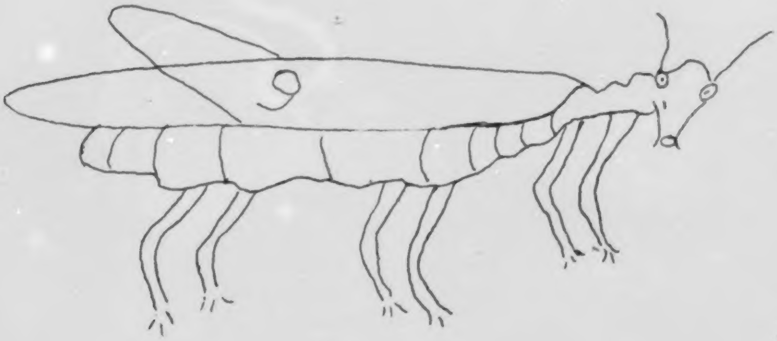
*Here is an example of one situation that can be reproduced to enable the children to learn more about bees and their social organization and hierarchy. Then the roles of worker and queen bees could better be appreciated.
No other examples will be referred to specifically; but the teacher is advised to check children's observations and conclusions always. That way she can readily help them draw the best out of their learning situations.

When young he loves living in red flowers, especially roses. On growing wings he changes colour and becomes greenish, yellowish and blackish in appearance from purple. This insect has two numbers on its sides on its wings which are 6 and 9 surrounded by the three colours namely green, black and yellow. It is indeed these numbers which made us call him 9 - Desemba, remembering the colour of our Independence Flag. He is very attractive to look at, and gentle.



When young he very much likes to sup waterings found in flowers only, although when he grows up he leaves this place and begins to find food suited to himself. His food at this stage is butterflies. When we neared him we had collected butterflies for him. He very much likes eating those parts of the wings which are powdery. He himself waylays the butterflies among flowers when they tap the water and catches them and stings them one by one with stings on his belly. We caught one and nurtured it in a big mug from 2.5.1969 and he fully grew as we continued supplying him with butterflies and a little water.

His belly is long and elevated and thorny which gives him protection. His head is small and has wings and six legs. The appearance of this insect is very attractive. I am not quite sure whether in 1970 they will come out with the same numbers 6 and 9. We shall wait and see.

INSECTS WITH THREE PARTS

Londoza (Wasp), Majimoto (Hot-water Ant), Nyuki (Bee), Sia (Safari and like), Sungusungu (Large Black Ant) Inzi (House Fly) 9 - Desemba (Praying Mantis), Nyenze, Nyenyele (Small Black Ant) Kipepeo (Butterfly), Kumbikumbi (Winged termite)

Sia

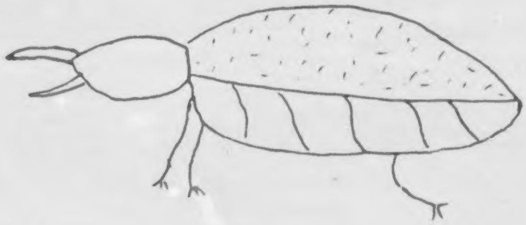
This is an insect which merely leaps a long distance. Its wings are rather short and this is why he is unable to fly with his wings like the grasshopper. He resembles the grasshopper except that his colour is greenish. This insect is large in size and loves living in green grass which is tender coloured like his body. His eyes are big and white. This green colour helps him greatly because when hidden in green leaves he is not easily detectable by his enemies, for instance, birds, other insects or even us children. His food is tender leaves or substance that is really soft. His head looks small because his eyes are very big.

INSECTS WHICH LIVE UNDERGROUND

Nyenyele, Mchwa, Fukufuku, Siafu

Fukufuku

Fukufuku is one of the insects which have no eyes and which lives underground. It is an interesting insect because instead of moving forwards like other animals it moves backwards. It has six legs; four fore-legs and two hind-legs. Two of its fore-legs are much longer and the hind ones which it uses to push itself and to lift his stomach so that he can move are very short. His head is very small and has two horns which serve in place of eyes. His skin is thin like that of a python.



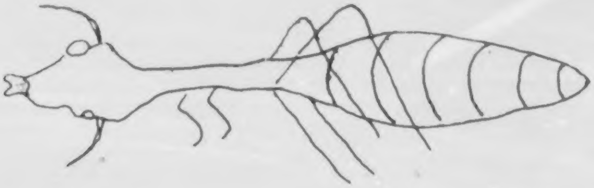
His food is mere mud because he lives in dry mud. In time of rain if he is soaked very much the poor creature dies because his life is short.

INSECTS WHICH LOVE LIVING IN TREES

Majimoto (Hot Water Ant), Mchwa (White Ant)

Majimoto

Majimoto is an insect which loves living in fruit trees like mango-trees, guava trees and the like. Majimoto has three part in shape which are head, chest and stomach. His eyes are greenish. His waist is narrow and his legs are light. He very much resembles the safari ant. His colour is coconut like.



His real food as we observed is fruits. This insect is very aggressive and this is why, I think, is the origin of his being called Majimoto, because of his aggressive habit of biting and moving quickly. If one attempts to arrest him he hastens his movement and to catch him is a big problem. In fact he is a very fierce insect.

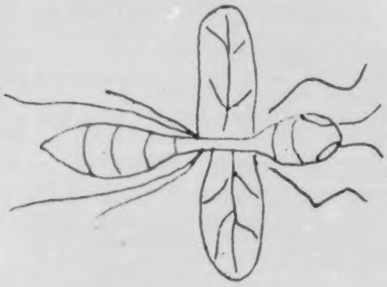
Londoza

Our observation of the Londoza is that he is not very much distinct from the bee. The real difference is that Londoza has no hairs on his legs. Secondly, his stomach is round in shape and has no lines.

Thirdly, he does not build a good house like that of the bee. Londoza is very aggressive if you disturb him and especially if you demolish his house. He uses his sting like the bee in defending himself. If he stings you in the face, the face will swell at once.

His food is watery substance and he likes catching grubs like "Washawasha" whom he carries to his house for food. He builds on house roofs or on the walls near the roof.

This insect has three parts and its waist is narrow.



These insects like living in swarms helping each other in their work.

INSECTS WHICH ARE ATTRACTED BY LIGHT OF LAMP

Kumbikumbi (Winged termite), Senene (a kind of green grasshopper)

Senene

Senene is a kind of green grasshopper. They love staying in lamp-light. Many people use them for food. On approaching a lamp light it does settle and if you do not catch it, it can put the lamp off. I saw a certain woman roasting them and eating them with food.

To prepare it until you eat it you do as follows: You first fry them until they are almost charred then you remove their wings and apply cooking oil and then eat them.

OTHER DIFFERENT GROUPS OF INSECTS

Wingless Insects:	Siafu, majimoto, nyenyele, mchwa, buibui (spider), chunguchungu, tandu (centipede).
Those with Six Legs:	Panzi, Senene, nyenze, mndewa, chawa (lice), majimoto, mvuvuele, mkimbia, 9-Desemba, inzi, siafu, nyuki, mtoamkia (with tail raised), fukufuku, mchwa, sia, chunguchungu, londoza, kipepeo.
Those Which Come Out During Rain:	Jongoo (millipede), Konokono (snail), Chambo.
Insects Which Live in Houses They Have Built Themselves:	Buibui, mchwa, londoza, nyuki, mvuvuele, majimoto, fukufuku, nyenyele, kumbikumbi.
Those Which Build Houses of Mud:	Mchwa, fukufuku, nyenyele, siafu.
Insects with Thin Waists:	Londoza, majimoto, chunguchungu
Insects Which Cause the Body Itching:	Washawasha, Funza (jigger)
Insects Which Eat Cloths and Paper:	Mende (Cockroach), Mchwa.
Eyeless Insects:	Fukufuku, Chambo
Insects with Ten Legs:	Ngadu (scorpion)
Insects with Multiple Legs:	Jongoo, Tandu, Washawasha

Legless Insects: Chambo

Insects which Live in Water: Ngadu, Mkimbia

Cunning Quick Moving Insects: Kipepeo, Mende, Inzi, Londoza, Mkimbia

Insects with Wings: Kipepeo, Panzi, Londoza, Senene, Sia, Nyenze, Mndewa, Mvuvuele, 9-Desemba, Inzi, Mtoamkia, Nyuki, Kumbikumbi

Inzi (House fly)

This is a very well-known insect by every human being and most hated because of its filthy habits. Its shape is slightly like that of a bee except that its colour is greyish. It has six hairy legs which help it to collect dirt. You will see it anywhere especially in dirty places.

Because of its filthy habits it spreads diseases like diarrhea, eye diseases and others. It lives in dirt and lays its eggs therein. Its food is just filth and filthy things.

Buibui (Spider)

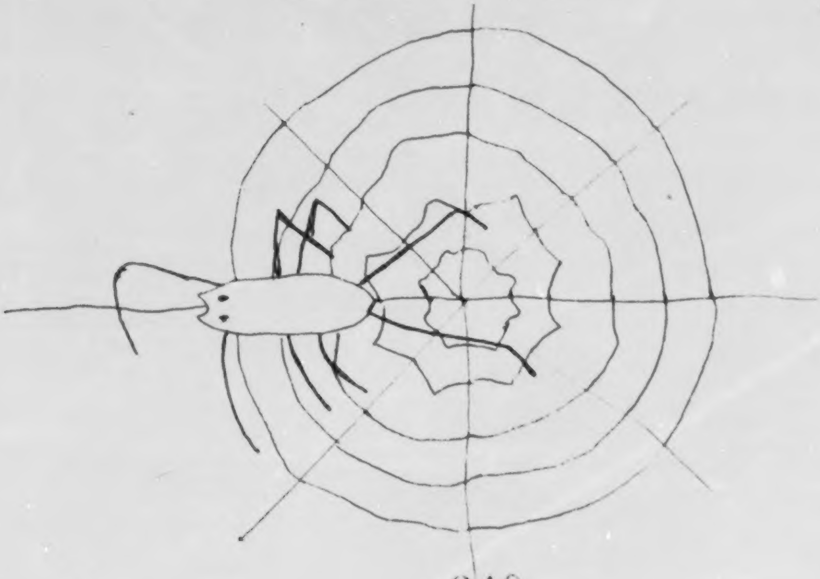
There are two specific reasons which prompted us to choose the spider in order to study how it lives. First, this insect is found everywhere and therefore it is easy to observe it. Secondly, it is a tame insect and has wonderful skill of weaving.

Spiders are a special kind of insect, more so in the way they live and enjoy their lives by using threads they produce from their stomachs.

If you are looking for spiders you will find them on the walls at the corners of houses, on trees, in holes, under desks, on the windows and under the tables. The spider has two distinct parts which are the head and the stomach. Its legs are long and light. On the head there are eyes and mouth. Generally its stomach is very big. It has no wings and therefore cannot fly.

We have discovered that there are five kinds of spiders here near our school, Kigurunyembe. First, there are those which are very fond of building and living in people's houses. They like living at the corners so that they can set their traps securely. Also insects like mosquitoes love hiding in these parts of the house. In fact it is easy for the spider to construct his trap. Spiders of this kind are long and have long thin legs so that they can move fast. Their houses are small in size and they do not put so many threads as some spiders do because they are always in their houses and are not afraid of rain or wind. They can catch any kind of insect with their threads which are somewhat hard.

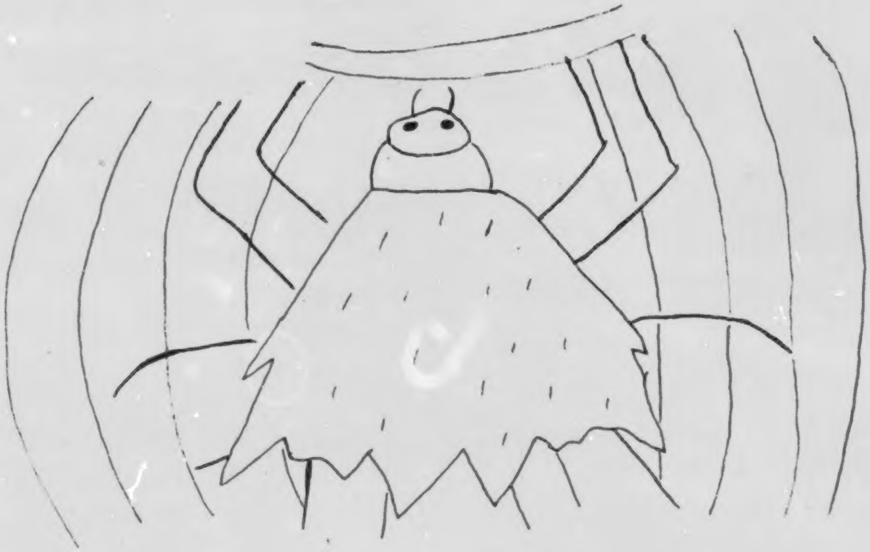
The first kind of spider:



The second kind are those spiders which build their houses on trees. They spread their threads around little branches or arms of the trees and live in some kind of rooms which they build to trap insects and catch them for their food. The spider of this kind hides itself in fear of its enemies the birds, chicken hawks and men. The houses of these spiders are much bigger and strong and can withstand rain and wind. Their threads are knit closer and are so many and sticky compared with those of the first kind.

They are very quick in building their houses and it is easy to do so because all they need is to produce the thread from their stomachs for the work. The houses of these spiders do not demolish easily and even if it rains heavily the drops are trapped on the surface and do not enter inside at all as we have seen with our own eyes. If a small insect like the housefly is trapped it can cause little damage to the house but after killing it and sucking it the spider repairs the damage almost immediately by adding more threads. What a clever one! If a big insect is caught and destroys the house completely, the spider moves away entirely and builds a fresh one at another place. Spiders of this kind are much bigger and their legs are very strong.

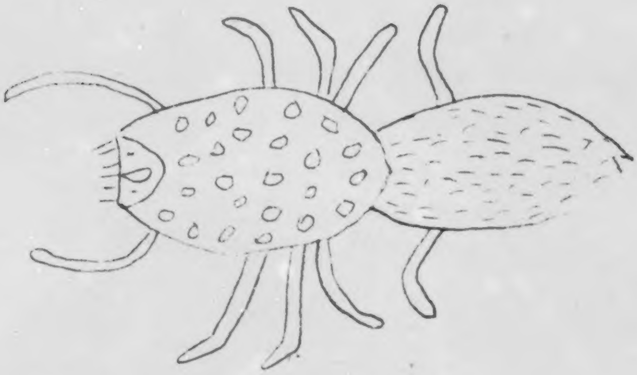
The second kind
of spider:



Spiders which build in holes:

These are large and their legs are not long but short. Their colours vary, some are grey and yellow, but many are red and their stomachs are big. Their houses are holes in the ground. If you peep into the hole you will be surprised how they have decorated their house so beautifully. Inside it looks as if they have spread very clean soft, white cloth. On the mouth of the hole they block with a covering which they have made in such a way that unless you are a very careful observer it would be difficult to find them. If an insect deceives itself and enters the hole it cannot escape being eaten. There is a certain kind of insect whose habit it is to visit any holes, these therefore become food for spiders of this kind. When it rains, water does not enter the hole at all because of the skilful way in which the hole is covered. Spiders of this kind only go out when they have been unfortunate in catching insects but very rarely.

Third kind of spider -
the hole spider:

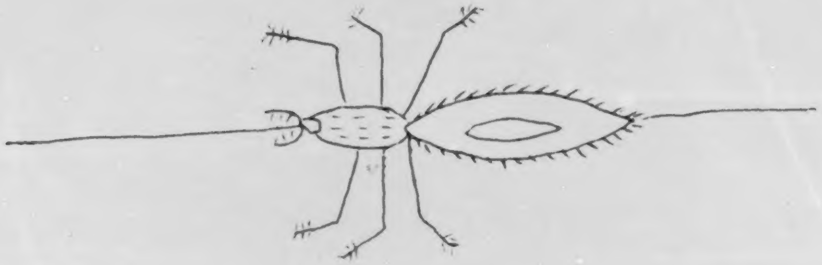


The spiders which build in the air:

Their houses or traps are attractive to look at. They have great skills like a man weaving a piece of cloth or knitting. These traps are usually set between two trees or house to house or from a tree to the ground. First it fixes one or two threads from one tree to the others. The threads are very strong. It then begins working on the exact position of trapping its enemies the insects. Then they pass without itself destroying the threads. When the trap is ready, it hides at the corner at the end of one of the threads and keeps quiet. When it feels the thread vibrating, it comes out to check and if there is an insect which has been caught, it runs fast following that particular thread and attacks and when the insect dies the spider sucks it and leaves the remains.

These houses get destroyed easily and therefore the spiders build new ones from time to time. Such houses are easily destroyed by rain or wind compared with those of spiders which build on trees or on branches of greens.

Spiders which build in the air



The fifth kind of spiders are those very big ones which have a horrifying appearance. Their bodies are hairy and their eyes black. They are extremely aggressive. It is said that if one of them bites you its bite is as painful as that of a snake. Its legs are long and strong. Their colour is light grey.

They are normally found in holes of tree barks. Unless you look carefully, you cannot see it well because it is extremely difficult to differentiate it from the bark of a tree. If you try to catch it, it raises its legs, especially the fore ones, and its head, with anger as if it wants to jump on you. If you want to catch it you must use a somewhat wide open tin to cover it and in this way its cunningness is defeated. Its movement is very fast. Unfortunately, we did not know what it eats because we even feared to look at it very closely although we caught it.

From the sole of its feet to the back of its back when standing it can have a height of about 3.5 c.m. It does not produce thread at all, its job is to travel looking for its daily food.

Spider Eggs

At first we thought spiders produce young ones and did not lay eggs because we had not seen their eggs. Later we saw some spiders with small sacs in their vents and every time they moved they had things round in shape and showed them to our teacher. We caught one spider and kept the eggs for a week and one day we looked into the tin and found that very many young ones had been hatched by their mother right inside the tin and had put many threads on the top to cover the tin. It is difficult to count them but we estimated there could have been between fifty and sixty of them or so.

The little ones are very small in size and are purple and muddy in colour and very cunning. The food we gave to them was house-flies and mosquitoes but we are not sure whether they ate them although they continued living until the second week when they began coming out one by one and disappearing completely.

Spiders are very good insects and do not cause us much harm and they benefit us greatly by eating insects which harm us like house-flies, mosquitoes and others. The only harm which those which build in houses do is to spoil the walls by their web.

SECTION IV:

SUMMARY

This section has shown some of the reasons for allowing children to study science on their own, to choose their own modes of investigation and to draw their own conclusions from personal observations and experimentation.

The message contained here is that the children are never too young to follow these procedures fruitfully, as long as they have selected them on their own. You will notice that they follow them with genuine interest and seriousness; that is the essence of learning.

While it is freely admitted that not all their conclusions are accurate, it is pointed out that for that very reason the role of the teacher is enhanced rather than diminished. Guidance of the children's learning takes on a clearer meaning. It is suggested that students and young teachers will always find it exciting to give children free scope to learn science in this way.

SECTION V

RELATING
WITH
CHILDREN

PENDULUMS

BUDS AND TWIGS

BURNING CANDLES

Science
20 24 28
60 16 50
12 16 12
22 17 22
24 20

ESTIMATING NUMBERS

MEASUREMENT

WATER

SECTION V

RELATING WITH CHILDREN

Introduction

In Sections II, III, and IV of this Handbook, you read about activities that employ an exploratory approach towards learning science. This approach is sometimes called the enquiry or discovery method. Section V explores some of the reasons the approach is advocated. An understanding of these reasons will enhance a teacher's ability to cope with teaching units developed for primary schools.

You will read about some concrete illustrations of individual differences as children grow, and also about how to cater for these differences in the classroom.

The first chapter illustrates this with a report of an observer of three different classrooms, and then goes on to discuss provision of materials, class organisation and suggestions for evaluation of children's work.

Chapter 2 deals with the important subject of intellectual development and stages of maturity of children. It includes actual conversations with children of various ages.

Chapter 3 points out the fact that children have their own ways of viewing natural phenomena, and also gives examples of real situations.

Chapter 4 is concerned with the kinds of things that "turn on" children and keep them going. A description of a class experience, where the teacher recognized the children's interest, is also included.

The final chapter of this section emphasises the great influence that culture and environment have upon learning.

Chapter 1. Teaching Science by Recognizing Individual Differences

Introduction

Central to the enquiry approach is the idea that the teacher must give each learner an opportunity to learn for himself. This means that each learner be directly involved in working with materials most of the time, while at other times consulting with the teacher, and at yet other times with fellow pupils. From this pupil-material, pupil-teacher and pupil-pupil involvement comes the capacity to deal effectively with questions relating to the problems that arise from working with the materials. When a teacher allows each learner to confront a particular problem, it can be said that the teacher is using an enquiry method. The process brings out the best from each learner and the teacher can be said to recognize individual differences.

Recognizing Individual Differences

The question then arises, why should the teacher recognize individual differences? Before an attempt to answer the question is made, we must attempt to clarify what 'to learn' means. A visitor going through a cross-section of classrooms in any educational system can discern various teaching methods that are employed by the teachers. These methods limit the ways in which pupils or students can react to the learning situation.

The following account describes the experiences of Mr. Satu who made such visits. Mr. Satu went to a classroom in which the teacher was teaching the topic: "Fishes". The teacher started by drawing a diagram of a fish on the blackboard, labelled the parts and wrote down the functions of each part. The students responded by copying the teacher's notes. Upon completion of this exercise, the teacher turned to the class and asked the question, "What does the pelvic fin do?" A row of hands went up and the teacher selected one of the students. The student repeated with exactness what the teacher had written on the blackboard. The teacher said, 'That's good.'

Mr. Satu sat and listened intently to what was going on in the classroom. At the end of the period he made the following analysis of the lesson:

> "The atmosphere of the classroom was quiet, almost tense; the students copied the teacher's notes, but upon examination of some of their exercise books errors in spelling were detected. The students were required to commit the information to memory."

After the lesson Mr. Satu wondered to what extent this lesson would contribute to the intelligent behaviour of each student in a new set of circumstances.

Mr. Satu went to another classroom where by some coincidence the topic being taught was "Fishes". In this class each student was given a fish to observe, draw, label, and write down the functions of each part. Further each student was asked to compare the external features and functions of his specimen with those of others which the teacher had brought to the classroom. The students worked mostly on their own with occasional help from the teacher. At the end of the lesson, the teacher asked the students to consider in what ways the external anatomy of a fish adapts it to live successfully in water.

In analyzing the lesson, Mr. Satu noted that the students were provided actual specimens, they were required to relate information they gathered on their own to other kinds of fish, and that to be able to answer the teacher's questions the students had to do more than merely recall the information which they had acquired. Mr. Satu concluded that some depth of understanding would be achieved by the students. Therefore he labelled this interaction the understanding level of operation.

Continuing his observation, Mr. Satu went to another classroom, where he found to his amazement that the teacher was teaching the same topic - "Fishes." By this time it dawned on him that the educational system was operating on a highly centralised model, with common syllabuses, time-table etc. In this classroom, the teacher started the class by posing the following problem: "What enables fishes to move in a straight line?"

The question posed by the teacher caused each student to make himself/herself a part of a group that would work on different approaches to part of the project that interested him/her. One group was to construct an aquarium in which the fish would be kept. Another group was to make fishing nets, and a third group was to go to the library to look up information on the problem. Near the end of the period the class got together and decided on a suitable time on Saturday when they would go out and collect the fish.

Mr. Satu noted that in this class the students were put in a problematic situation which pressured them to concentrate their thinking on the problem. By doing so, the students utilised information they had previously acquired to solve the problem. Thus Mr. Satu concluded that the students were doing a lot of thinking and were therefore operating on a reflective level. He also noted that the teacher was recognizing individual differences.

At the end of the day, Mr. Satu noted the three levels of interactions which he had observed in the three classrooms. In the first class the nature of the interaction was such that the students were committing factual information to memory. But given a different set of circumstances, would the students be likely to transfer that information? If not, then memorization is not appropriate if the intention was to accomplish any meaningful learning.

In the second classroom he noted that the method employed by the teacher enabled the students to isolate units of information and to see how these pieces fit together and that therefore it could be said the students understood what they were doing. Because of the absence of discussion it cannot be said whether the students were critical or not about the information which they had acquired. The students were nonetheless operating at an understanding level.

In the third class the problem posed by the teacher set the whole class in motion and demanded that the students reflect on the problem. In thinking deeply about the problem the students utilized available sources of information, constructed equipment, collected specimens. From the specimens, data would be obtained, the analysis of which could provide possible answers to their problems.

The evidence from the classroom observations enables us to deduce certain ideas about what 'to learn' means. To learn can be merely to make a carbon copy of information in our minds. It can also mean that information must be fitted into an individual's existing intellectual structure and that this structure itself induces change in the process. Committing information into one's intellectual structure makes learning a highly individualistic activity requiring the total involvement of the learner. The teacher, by providing appropriate material can stimulate and provoke individual learning, but this only occurs as a result of changes that take place in an individual's perception of the experience.

> Using the concept of individual delineated above, to what extent would you say that learning took place in each of the classrooms?

To answer this question we must have goals clearly in our minds. For instance, do we aim at creating societies in which men can do new things? Or do we aim at creating men who can repeat with precision what other men have done for generations past? It would seem that the more desirable outcome to aim for is one in which students will learn very early in their lives how to find out new things for themselves rather than to just reproduce what has been learned. Unfortunately, treating a class collectively may not provide adequate opportunities for students to maximize their potential for thinking. Creative thinking is not a collective attribute, it is an individual activity. Therefore if the desired aim is one of fostering thinking, then the teacher must recognize and make allowance for individual activity.

How to Cater for Individual Differences

In the light of the preceding discussion you might, as a teacher, wonder what your role should be in the kind of learning situation that we have been describing. In the traditional classroom the word teacher carries with it the connotation of the doer. But should the teacher really be the doer, or should the learner be the doer? Imagine that you wish to teach a pupil how to hammer, do you think that you can do this successfully by giving him a lecture on how to hammer without providing a hammer and nails to the pupil? If your answer is no, you have a good grasp of what we have been talking about. With most of the exercises that you will be undertaking in this Handbook, the materials are the tellers, the pupil is the doer and the teacher is the guide and facilitator of the learning situation. Just as you cannot teach how to hammer by giving a lecture on hammering, so it is that you cannot get people to learn science without their involvement in the act of doing science. This is not to deny the fact that there will be times when the teacher is in front of the room comparing findings and discussing with the whole class a particular subject they have been working on in smaller groups. But we advocate that the main task of the teacher is to prepare what is needed, to keep track of what is going on and to ask the right question at the right moment.

When is the right "moment"? And what is the "right question"? As a teacher you decide when to intervene. Occasionally, a pupil may be bored, have finished his work or is frustrated. On such occasions a teacher may provide additional materials, or illustrate a new way to work with materials in order to stimulate further activities. The teacher might ask open questions that lead to problem solving. Usually questions which begin with "can you ..." or "what would happen if ..." are of this type. A teacher's question is open when a pupil can approach it in many different ways. Other questions are not so open. They require a word response from the pupil. An example of this type of question would be "name the parts of this flower."

Provision of Materials

In order to teach science the way we are advocating, an abundance of materials is required. Many of these things can be found in the local environment or purchased at little cost. Reading the various units within the Handbook will tell you what to prepare for each unit. But in addition there are certain types of materials that are valuable to have around all the time. These include:

Powders - Sugars, salt, soap powder, starch, baking soda and sand.
Liquids - Parafin, Kerosene, oil, spirits, fat and water.
Wood - Planks, poles, stems of trees cut into various lengths and sizes.
Paints - Flowers, roots, dyes and brushes.
Containers - Cardboard cartons, cube sugar boxes, clay pots, pots, calabashes, coconut shells, large cut cane, pans, jam jars, bottle stoppers, tins, match boxes, cigarette boxes and different types of shells.
Tools - Hammer, saw, drill, chisel, screw driver, matchets, knife, balances, collecting nets, string, rope, microscopes, hand-lenses, candles and matches.

The teacher and the pupils can think of many other items to include in the list. An important source of these materials is the pupils themselves; when they know that the materials they bring will be used in class they are usually more responsive to the teacher's request.

Class Organization

Teachers often raise the problem of class organization when newly confronted with this kind of activity. Children may work independently or in small groups. The number of children in each group usually depends on the type of activity in which they are involved. A good rule of thumb is that the groups should be small enough so that each child is doing something. If groups are too large or the materials are not sufficient, some children will probably sit back and watch while others are working. The children become bored and find disruptive activities to get involved in. This condition is one of the most common sources of non-constructive noise and "discipline" problems.

Ideally, discipline problems should not arise if children are working, but this requires the teacher to provide stimulation at the right time. With very large classes this is difficult, but not impossible. In large classes, management problems can be reduced by encouraging children to share their experiences with those in other groups. Whenever it is possible, children should work outside the classroom; this has the added advantage of making them more aware of their environment. Also it allows more freedom for the children to talk without disturbing other classes.

Science classes require extra time for set-up and clean-up. Some teachers work out a time-table at the beginning of each term (or year) whereby they can have double periods for science. Many science topics relate very well with other subjects such as mathematics or crafts. It is therefore possible for the class periods for those subjects to be shared with science in order to give the children the opportunity to really progress in problem solving situations without being cut off by the somewhat artificial limit of the bell.

Evaluation

Evaluation is usually a problem for the teacher just beginning to work with children in the way we are advocating. One way to approach this problem is to keep cumulative records of information that is routinely collected about each child. As often as possible the teacher should make notes of what each child or group did. The teacher can then evaluate performance on the way each child actually solves problems, and the kinds of questions that the child asks. By observing and listening to each child while he is in the act of learning, we can assess the quality of his understanding and development. When observing children we can ask ourselves questions which will indicate to us the child's overall development.

- What sort of questions does he ask? How do his questions change as he gains experience?
- Does he make measurementsand collect information that will help him to solve problems?
- Is he able to collect or improvise materials?

- Does his skill in handling materials improve?

Some teachers realise that there are important things for children to learn which written examinations cannot measure:

- Do the children develop confidence in themselves and their abilities?
- Do they respect the ideas of other children?
- Do they enjoy learning and want to learn on their own?
- Do they know important things about their own localities and have interest in finding out?

By taking account of all these questions the teacher should be able to evaluate the performance of each child by the end of the term, even without the formal pencil and paper test.

Chapter 2: Intellectual Development

The word development has several connotations. It might imply an increase in quantity such as the addition of new rooms to school; it could also mean an improvement in quality when it refers to standards of instruction. The first connotation is physical and the second is conceptual. Thus we can talk of a child's development as increase in size and as intellectual growth.

For convenience, it is possible for us to talk about either physical or intellectual development separately. However, we do so only with the understanding that both processes are inextricably bound together and are going on simultaneously within the same individual all the time.

In view of our familiarity with physcal development, we build up certain expectations of performance of children. For example, when we organize sports for children we classify the participants as juniors, intermediates and seniors. These groupings are usually based on age, height and weight. It is precisely because of the recognition that children of different age groups, and sometimes of the same age range, perform differently that psychologists maintain that maturation is one of the major factors that determine a child's level of readiness to benefit from learning experiences. Thus there is an established relationship between physical development and intellectual development and this relationship has significance for those who provide learning experiences.

Our main task is to look more closely at intellectual or cognitive development. Cognitive development is concerned with the changes that occur in the child's way of: forming concepts, perceiving, thinking, and solving problems as that child grows older. Let us examine first the idea of concept formation. Consider this question: How does a child come to recognize that two or more perceptually dissimilar objects can be considered similar? Tasks were arranged for children to engage in. In this task the children were given familiar everyday objects to classify into "resemblance" groups. Consider the following conversations.

Iye (7 years)

Exp: Another child came here and made these groups for me. He took the corn and the pencil and put them together. Can you tell me why he put them together?

Child: Yes

Exp: Why?

Child: The corn and the pencil resemble.

Exp: How to they resemble?

Child: The skin (points to the colour)

Exp: After that, he took the pencil and the chalk and put them together, can you tell me why he did that?

Child: They don't resemble.

Exp: What would one do with a pencil?

Child: He writes with it.

Exp: What does one do with a chalk?

Child: He writes with it.

Exp: Do you think that these two things resemble in any way?

Child: They are not things that resemble.

Exp: Even though they do the same things with them?

Child: Yes.

Exp: After that, he took the corn and the bean seed and put them together, what did he have in mind?

Child: They don't resemble.

Exp: What do they do with beans?

Child: They cook them.

Exp: What do they do with corn?

Child: They plant them.

Exp: What about beans?

Child: They boil them, put them in sauce and eat them.

Exp: Is that the only thing they do with beans?

Child: Yes.

Exp: How do people get beans?

Child: If you want beans you go and beg from some other person and then you come and plant them.

Exp: So beans are planted?

Child: Yes, they plant beans.

Exp: What about corns?

Child: They plant them also.

Exp: So beans and corns are things that are planted?

Child: Yes, they plant them.

Exp: Do you think that, that is a resemblance?*

Child: No, they are not things that resemble.

Exp: After that, he took the grass and put it together with the bean plant, what thoughts did he have that made him do that?

Child: They resemble.

Exp: How do they resemble?

Child: This and that are the same colour.

An analysis of this conversation will show what this child understands by resemblance. Here is one analyst's opinion:

> The first observation that we can make from this conversation is that this child can shift from one colour criterion to another. For example, she could recognize

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* Resemblance is the closest word that expresses similarity in the child's language.

the similarity between the corn and the pencil and that of the grass to the bean plant because each pair has its own colour. We therefore note that although these objects are different in form, she can coordinate the differences when the objects are of the same colour. In short, she can recognize similarity among different objects of the same colour. On the other hand she consistently rejected similarity between the chalk and the pencil, and that between the corn and the bean seed. From this behaviour, one can see that for her, similarity does not include function similarity.

Can we explain her inability to shift from the perceptual criterion of colour to the abstract attribute of function? We can. It is clear that the child has the notion of function because she knows what one does with a chalk or pencil. But at this stage of her thinking, the notion of function seems to be specifically tied to one object. In other words, she cannot compare two objects in terms of some abstract attribute such as function. When the child compares the objects with respect to colour they are the same. But she cannot compare with respect to the attribute of function because function does not yet have an existence apart from the object that is doing the functioning.

Consider the following conversation on the same task but but with an older child:

Chris (11 years)

Exp: I want you to make groups with these things. Put together in one place all the things that resemble each other. Use any kind of resemblance that you can think of that will enable you to explain to me why the things that you have put together resemble each other.

Child: Corn - Pencil ... yellow

Bean Plant - Grass ... green

Knife, candle, chalk, egg ... white

Exp: Now you have made colour groups, I want you to think of another way in which you can group these things besides colour.

Child: Chalk - Pencil ... things to write.

Bean Plant - Grass ... plants.

Egg - Corn seed, etc. ... things to eat.

This older child is able to shift from one category to another with ease. More importantly, the older child demonstrates that there is a basis for putting things together by first thinking of the criterion of the group and then selecting those things that belong to that group. These conversations with the children tell the teacher a great deal about children and about teaching and learning. The first and rather obvious observation that you can make is that what constitutes a resemblance to Chris does not to Iye. Iye's concept of resemblance is limited to the concrete aspects of the objects. Therefore, her concept of resemblance is not yet completely formed. We can say that Chris has certain intellectual tools - way of thinking - which are not yet available to Iye. What other reasons can you think about? In your science class, how would you handle a situation like Iye's in which she is unable to accept functional similarity? An examination of children's thinking might help you answer the second question.

There are four main stages that the child's thinking goes through from birth to adolescence. To these four stages, a Swiss psychologist called Jean Piaget has given the following names: (1) the sensory motor stage, (2) the pre-operational, (3) the concrete operational and (4) the formal. The change from one stage to the next is marked by a definite land mark. The sensory motor stage lasts from 0 months to about 18 months. About the end of this period, the child comes to discover that objects do have permanence. To reach this conclusion, Piaget performed experiments with babies in which he took an object with which the baby was playing and covered it with a piece of cloth. When he did this, he noticed that the child made no effort to search for the object because a child that age thinks that when the object is out of sight it has ceased to exist. It is not until about 9 months old that the child attempts to search for an object that is immediately out of sight.

When the child attempts to search for an object that is out of sight, it indicates that although an object is out of sight it does not cease to exist. Therefore, that child has acquired a sense of object permanence. The acquisition of object permanence is the first major change that occurs in the child's intellectual development.

The second or pre-operational stage lasts approximately from 2 years to 7 years. This stage is characterised by the appearance of language and the extensive use of immitation. A child at this stage is not yet able to think in terms of operations. For instance, the child does not realise that things that are put together can be separated, or that a temporary change is not permanent. For example, you can do this little experiment to find out how the child thinks. Give a piece of plasticine to a child in this age range. Ask him to divide it into two equal portions making sure that the two portions are equal in amount. Then take one portion and change the shape by flattening it. Ask him again whether the two plasticine portions are now equal. You will be quite surprised to find out that most children in this range will say that the two portions which they had said were equal are no longer equal because the shape of one has been changed. A child who says that the two equal portions are no longer equal because of the change in shape ... (transformation) is said to be a non-conserver. He is a non-conserver because he thinks as if the temporary change that has taken place is permanent; that he cannot think of reversing the flattened shape to the original shape it had before the flattening took place.

The concrete operational stage (7 - 11 years) comes into being when the child acquires conservation. This means that the child is now able to carry out certain simple operations in his head which before now he would have had to do through manipulation of actual objects.

According to Piaget there are three operations that underline the notion of conservation. These are identity, reversibility and compensation. To give us a better understanding of what these terms mean, examine small portions of conversations with children doing the task of conservation. In the experiment, the children were made to think that the plasticine represents rice-flour-bread (which is familiar to them). The conversation continues after the child has agreed that the two portions were equal.

Abass (7 years)

Exp: This ball is yours and that's Oju's. See what I am going to do. I am going to take your bread and break it into little pieces. As these are now, if you want to eat your bread and Oju wants to eat his, which of you would have more bread to eat?

Sub: His is big and balled.

Exp: So what would that do to it?

Sub: It is big.

Exp: Did it increase?

Sub: No. they are equal, but when you made this into pieces that's why I think that he has more.

Exp: If you want to eat your bread and Oju wants to eat his which of you would have more bread?

Sub: It is equal.

Exp: Why?

Sub: I saw them before, and they were equal.

Exp: What else?

Sub: His is whole.

Exp: So what does that mean?

Sub: The reason for that is that they were equal before and they have not added to his and they have not added to mine and they have not reduced.

It appears that Abass first thought about the number of pieces without thinking about the amount he had to eat. As long as his attention was focussed on the number of pieces, the ball was bigger than each piece. However, the question about increase forced him to think about the amount he had to eat. The question seemed to have raised a conflict between what is apparent ... the number of pieces, and what is real ... the amount of bread to eat, and that made him realize he would not have more bread to eat than Oju. To reach such a conclusion he had to mentally integrate the pieces into a whole, and then compare the wholes. The mental comparison of the two wholes forced him to the conclusion of equality. However, the mere assertion of equality does not tell the experimenter anything about the operation that led him to the conviction that both are still equal. What led to that conviction is the operation of identity: "they were equal before and they have not added to his and they have not added to mine and they have not reduced."

In another case a child was asked by the experimenter to tell what she would do to show him that both she and her friend would have equal amounts. She replied by saying that she could roll the pancake (shape) into a ball. Reversing it back into the original shape implies the operation of reversibility. In the case of the operation of compensation, the child has to recognize that when, for example, the ball of plasticine is rolled into the form of a sausage it looses thickness. But what it looses in thickness it gains in length; so that the child comes to recognize that a loss in one dimension - thickness, is compensated for by a gain in another dimension - length. It is this realization that enables a child to assert equality in spite of the change in shape or form.

The preceding two stages cover the period of the elementary school child. The last or formal stage begins to appear from 12-15 years. This is the time when the child acquires ways of thinking that are similar to those of the adult. What this means is that the child as an adolescent is now able to reason with verbal propositions (words) without necessarily having had that experience or performed the action which may be the subject of the discussion.

You might have been wondering as you read along just what this discussion has to do with you as a classroom teacher? It has three implications for you. The first is that children's thinking goes through stages and a knowledge of where the child is, is essential to you if you are going to work with children fruitfully. This knowledge enables you to plan effectively appropriate learning experiences for children of different ages.

The second implication is that the way in which children reason about their environment is different from those of adults. For example, children in the concrete operational stage often believe that the moon follows them as they walk along at night. A teacher who attempts to give an explanation that is different from the one the child holds will face difficulties, since children do not automatically give up their convictions. On the other hand, the child's notion fits fairly well with his observation rather than the known scientific explanation. This means that children have their own explanations of natural phenomena and they do not easily become influenced by different explanations no matter how reasonable they appear to the adult. And it is not that they do not want to accept these adults' explanations, it is just that they are not able to accept them because they do not yet have the intellectual tools that enable them to do so.

The third implication follows from the second. If in fact, children have their own explanations about the world, how do we get them to substitute their unscientific reasons with our scientific explanations? The truth is that we cannot.

The question should be: how do we get children to learn? The teacher has to begin by first acknowledging that the child's approach to solving problems is different from his own. The elementary school child learns mostly by interacting with things in his environment and working with materials affords him the opportunity to ask his own type of questions. As he grows older, he reaches a developmental state at which the interaction between the material and his experience will force him to abandon his previous convictions for better explanations. This is a process and requires a lot of opportunities for exploring different kinds of materials under different circumstances. When the teacher presents an advanced idea at an inappropriate time, the child might remember the words used but not the reasoning underlying the explanation. This is rote learning. However, when the child begins to doubt the correctness of his explanations, it is the right time for the teacher to intervene by providing examples of materials that will help him test the accuracy of those explanations.

SOUND: LOWER PRIMARY

SOUND: UPPER PRIMARY

Chapter 3. How Children View the External World

One of Jean Piaget's most important contributions to our understanding of children is his emphasis on accepting children for what they are. In his clinical approach to the study of the child, childhood is not just seen as the absence of adulthood but rather as a complete state in itself. Thus, children have their own particular ways of viewing natural phenomena. Our purpose in this section is to throw some light on some of the ways that children view the external world.

We stress once more that while children at the same developmental stage may have several common characteristics, each child is unique and singular in his or her own way. Some children are shy and reserved, others are bold and adventuresome. Some ask many questions, some ask few questions and others have to be prompted to ask any questions. Some will volunteer to try anything, others will not even elect to demonstrate things they know.

That the thinking of a child is unique was clearly demonstrated by a ten-year old in elementary IV in Awo Omama, Nigeria. After his class had tested different substances to determine which ones conducted electricity, he decided on his own to find out 'if electricity runs uphill.'

He obtained a bulb, a battery, a battery holder and a wire longer than the height of his classroom. Then he tested the intensity of the electricity generated by the battery and bulb at ground level. Following this, he left the battery with one end of the wire attached to the holder on the ground, climbed to the roof of his classroom, connected the bulb to the other end of the wire and looked at the bulb's intensity. Then he was heard rebuking himself. It had dawned on him that he did not remember the ground level intensity. He had no instrument for measuring this. He climbed down and had discussions with his teacher. Following this he tested several batteries and bulbs until he obtained two sets which yielded identical intensities. He left one battery on the ground, connected his wire and put the rest of his equipment in his pocket. Then he climbed the roof again. There he repeated his experiment, this time with a difference. In addition to connecting the bulb to the other end of his wire and finding the intensity, he also observed the intensity of the electricity generated by the second set of battery and bulb not connected to the wire. He discovered that the intensities matched and thus arrived at the tentative conclusion that there was no loss of intensity due to height.

Another demonstration of uniqueness of thought came from a nine-year old girl in Njala, Sierra Leone. She divided 403 by 7 through the use of a box of Cuisenaire rods*. She observed that

$$100 - 7 \times 14 = 2$$

or

$$100 = 7 \times 14 + 2$$

and therefore that

$$400 = 4 \times 100 = 4\ (7 \times 14 + 2) = 4 \times 7 \times 14 + 8$$

Thus

$$403 = 400 + 3 = 4 \times 7 \times 14 + 8 + 3 = 4 \times 7 \times 14 + 11$$

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*This is a set of wooden rods in ten different sizes and colours. The lengths vary from one cm to 10 cm but the widths and heights remain constant.

She then divided by 7, the first part of the sum (i.e. 4 x 7 x 14) when divided by 7 yielded the result 4 x 14 = 56. The second part of the sum yielded 1 and 4 left over since 11 = 7 + 4. When the girl came up with the answer 57 and 4 left over, her teacher who was having problems keeping up with her was still baffled.

The fact is that most pupils, especially the younger ones, face new situations without many preconceived ideas. Sometimes, this helps them to make observations or carry out investigations that adults would not think of. If a teacher is aware of this and is willing to encourage this freedom to enquire, some benefits may be derived.

This uniqueness and openness is something that a teacher needs to look for and encourage. Teaching good science to children should emphasise helping each child to observe phenomena. If a child learns to use his senses he is well on his way to good scientific investigations. If he has a teacher who is a trained observer, and therefore a good listener, he may have some of the guidance that he needs as he tries to develop.

One related and important outcome of listening to the child may also be associated with the work of Jean Piaget. His clinical interview approach to the child has revealed that it is a mistake to view children's answers and questions in adult perspectives and thus to classify them on those grounds into right and wrong. This is because the acceptance of the stages of development implies the acceptance of the view that children's answers may be categorised in many ways related to their stages of development.

Furthermore, the adult manner of asking and answering "why" questions does not make much sense to many children because many answers provided to "why" questions are usually rooted in theory rather than experience. For example, the question: "Why does the ball fall this way?" has no satisfactory explanation that is based on experience. A more exciting question to ask a child is: "How does a ball behave when rolled across the floor?" Children like a question that deals directly with the materials of the world.

Chapter 4. Motivating Children To Learn

Associated with the nature of questions that a child has to answer is the issue of motivating him to learn. As was asked earlier; how do we get him not only to learn science, but also to learn how to learn science? Our position has been to advocate an approach that is rooted in investigations. When the child interacts with an object in a problem-solving situation, the nature of the stimulus provided to him should be such that he has to reflect on the situation. Thus, his thinking should go beyond both rote memory and mere understanding.

Our concern in this section is with the kinds of things that will "turn on" children and keep them going. To give you more insight into our thinking on how this can be done, we present this edited version of "Dennis Dungball: A Case History of Children's Activity." A teacher took her Standard VI class out on a nature study expedition around the school's playing ground. She wanted her class to observe that some insects, especially the dragonfly, could be found in the field. Sure enough, since dragonflies were abundant in the area the children ran into them. They became immediately absorbed in observations. They cut branches and started beating the dragonflies in order to have a close look at their structure. Some of the flies were completely smashed up while others had smashed tails. The children observed that this latter group of flies could still fly way, way up.

There was another group of flies with cut-off tails. This group could still move and try to fly but wouldn't get far. Then questions started to rise. How come they can move though they are injured? Can we substitute the real tail for an artificial one?

As you would expect, these questions called for further investigations. The children were able to answer the first question. Then they tried to substitute grass-stalks for real tails and let the dragonflies fly on these artificial tails. More observations were made. These raised more questions:

What do they eat?
How high do they normally fly from the ground?
Why do they follow people?

A group of children caught a dragonfly with a lake-fly in its mouth and concluded that the dragonfly feeds on small insects. They were able to make measurements of various heights flown by dragonflies. On the third question, they guessed that when people walked on grass they stirred up small insects which the dragonfly would then be able to catch for food.

Another group of children became involved in observing other insects including grasshoppers and dung-beetles. They became fascinated by the busy activities of the dung-beetle. They were interested in:

Its structure
Where it was found
How it made its balls
Where it carried its balls to
How far a ball was carried from the dung heaps
What is used for making each ball
How heavy a ball was in relation to the weight of the dung-beetle

How strong the dung-beetle was
How the dung-beetle stored its balls
How the dung-beetle reproduced
How several dung-beetles stayed in any one heap of dung
Whether dung-beetles could climb slopes
Whether dung-beetles could be kept for further observations
How many kinds of dung-beetles would be found in any heap of dung

The children worked on all of the above topics. From the first observation they proceeded to more difficult ones. The structure of the dung-beetle as well as its working habits occupied the first few weeks. In the process the children discovered many interesting things. One girl was surprised when she found out that her beetle was full of ticks. "I never thought even small animals like these could have parasites" she told her teacher who then encouraged her to find out if other insects in the vicinity could have parasites.

With the booster from the teacher the girl went looking for grasshoppers. She saw one, lifted up the wings and saw that there were two parasites which looked different. "I thought only people, cows, dogs and chickens had parasites - so every living thing has parasites", she said. The teacher was pleased that this girl could associate these parasites with lice that bother people.

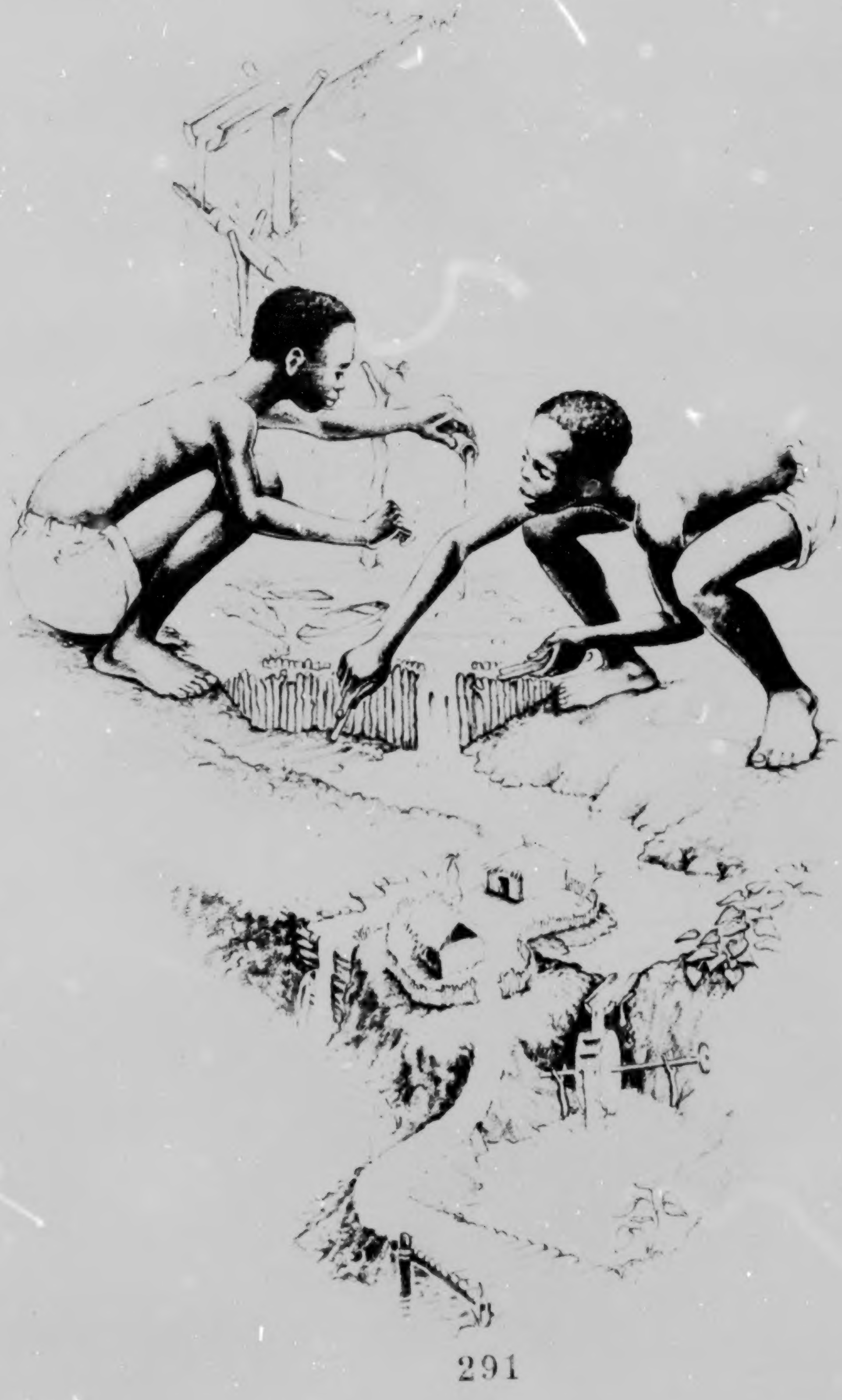
These and many other things happened. For example, while digging one day the children discovered egg balls instead of beetles. When they broke these balls open they found some eggs. This started a hunt which revealed many egg-balls. Some were attached to blades of grass while others were neatly packed in groups of more than twenty balls under tufts of grass or small bushes. Some balls were small;

others were large. The children discovered that those balls that looked fresh contained eggs while those that looked old contained either pupae or larvae. It was natural for the children to investigate stages of development among other things.

Then one day two girls brought a very big ball with two beetles on it. They took a balance and put the ball on one side and the beetle on the other. The ball went down. By adding more beetles they found out that they needed 15 beetles to balance that ball. They weighed separately a beetle and a small wet ball that it was carrying. The beetle weighed almost "nothing" but the ball weighed 5 gm. From here the children went on to more difficult weighing and measuring.

In the case history which we have just retold, you will notice that the teacher motivated the children by selecting a topic which captivated the children's interest. Also the teacher guided the children to raise good questions. Finding out the answers to these questions was rewarding and satisfying to the children. The case history emphasises that children get excited when they are working on something that interests them. This is what we call intrinsic motivation. It works as though something inside a person gets switched on when he finds work that interests him. Educators believe that this type of motivation is better than the other type of motivation known as extrinsic motivation. Unlike intrinsic motivation in which satisfaction is the reward, the most common form of extrinsic motivation used by teachers is punishment; occasionally a prize may be given for good work. Both prize giving and punishment are examples of extrinsic motivation that are not recommended because the incentives to achieve are not enduring.

There is another aspect of the story of "Dennis Dungball" which should not be missed. Children were playing, working, having fun, and learning. What is more it would be extremely difficult to try to draw a distinction between when they were playing and when they were working. But luckily for us that distinction need not be drawn. What is more important is that the children were doing, experiencing and learning. A teacher needs to keep in mind that the distinction by adults between work and play is artificial. Children do not differentiate between work and play - they just "do". We should encourage them to participate in activities that are rewarding.



Chapter 5. The Role of Culture in the Learning of Science

Three Aspects of Culture

There are many courses of behavior, mental or physical, from which an individual could choose. But usually the course he chooses is determined by culture. Every human being strives to cope with his environment. Gradually but surely the newly-born child acquires facility with an understanding of the things around him. His people's ways of doing things become a part of him and he learns to relate to objects through these ways. It is the sum total or totality of these habits of his people which we call their culture. Any person who is not familiar with these ways of doing things is said to be alien to the culture in view. He is not socialized.

Each child, from birth, has its needs and wants. Some of these are common to all human beings but every culture has its scheme of what is desirable and what is not. It also has a way of indicating approved means of satisfying needs and wants. The approved ways are communicated to each new generation.

Thus children are brought up in differing ways in different societies. In traditional Africa young children learn correct speech, proper behavior and the traditions of the family, clan and ethnic group from mothers and other relatives. They learn how to cope with their environment. Through observation, imitation and participation, older children learn to farm, hunt, cook, sew, fish, play, wrestle, deliver messages or build houses. Teachers include most members of the extended family and (often times) secret societies. Clearly the type of education is practical, informal and mostly non-verbal. And, as in other societies, it is this ability of youngsters to learn from the adult world which preserves the cultural values of the community.

There are two more aspects of the culture variable which are pertinent. We referred to one of these earlier. While discussing individual differences, how children view the external world, and motivating children to do science, we stressed that children have a culture all their own. The types of questions they ask, the kinds of answers they give, the types of comments they make are all part of this culture which transcends ethnic boundaries.

The remaining aspect of culture that is relevant to this situation is the culture of science itself. Science has its language, symbols, values and methods. These form part of the culture of science; a culture which scientists believe that all would-be scientists have to come to terms with.

We will not disagree with the objective of expecting learners to be acquainted with the culture of any subject they study. However, there are several ways of achieving this objective. Often in the past adults have taken things that adults do, simplified them to levels considered appropriate for children and then asked children to do them. We have already indicated in earlier parts of this section that we hold dear the concept of teaching science to children within their own culture.

A tragedy of science education in Africa which adults and children have shared is that it has not always paid attention to the culture of the African. In the recent past there was a lack of adequate knowledge of the local cultural environment which was in any case dismissed as wholly inimical to the development of science concepts. The dismissal was clearly unfortunate because even if African culture is totally inimical to the development of science concepts, it would be useful to study the African environment from the standpoint of knowing what to avoid.

But the issues are even more basic. The individual is oriented to objects in his environment and this orientation must play an important role in the way he learns. His language, the symbols he uses, and his behavior patterns are all an integral part of his intellectual growth.

Interaction of Culture and Learning

Perhaps an incident that took place in Sierra Leone will help us to bring home the importance of the point that the environment affects science learning. The scene was at Njala and the conversation took place between a member of the staff of the Science Curriculum Development Center and a lower secondary school boy, Momodu.

David: Momodu, am I counting correctly in Mende?

Momodu: No, because you counted your thumb as one and that is not the way we do it; we start with our little finger.

David: Do you know why, Momodu?

Momodu: No.

David: But don't you want to know why?

Momodu: No, I have school work and other important things to do.

David: Suppose I were your teacher and asked you to find out why, would you do it?

Momodu: Yes, but if I asked my mother she would say that my dead grandfather who always did it that way did not tell her why.

David: But, Momodu, if I did not know any Mende people and I wanted to know how many fingers I had on one hand, how would I find out?

Momodu: You would count them.

David: But, would I get the correct answer if I counted from my thumb?

Momodu: Yes, but that is not the way we do it.

Would you say that Momodu did not know how to count?

Many times, in fact, a deep understanding of the culture is necessary for proper interpretation of interactions, responses or feedbacks. Kamara and Easley have made this point. Equal balls of plasticine representing equal portions of rice cake were given to pairs of Themne children. In each case one member of the pair would claim that an older partner had more or a younger partner had less since fair distribution of food in Themne culture required that older children get larger portions than younger ones. Here the mathematical concept, 'equality' was viewed in the context of Themne traditional culture.

Another account of the interaction of culture and learning has been given by Mary Budd Rowe. She worked with groups of suburban and ghetto children in the City of New York. Among other things, she observed that the former got excited about the death or disappearance of guppies and snails and asked questions such as "what happened?" or "where did they go?" but the latter didn't get turned on. Ghetto children, she commented, are used to having people come and go.

Relating Science Learning to the Culture of Children

It is exciting to observe what happens when a good attempt is made to relate science learning both to the culture of children and to the culture of the larger society. Butterflies are common in many parts of Africa. Monrovia, Liberia has its share of them and so a kindergarten teacher who knew that children like butterflies used them to teach addition, subtraction, life cycle of animals and symmetry. She came to school one day and set up two butterfly nets outside her school room. Those nets have remained in the school yard for more than two months during which they have attracted the attention of many children in the school. Besides, many pupils have had their parents hunting for butterflies and moths.

In particular, the teacher's kindergarten class kept a record of the number of butterflies caught each day by each of the two nets and deduced the total number caught per day. One day one of the children observed a dead butterfly in one net. That started the children recording the number of deaths per week. Subtraction problems were then built upon these records.

But the most exciting experiences were yet to come. In the third week one child brought a caterpillar to school. The class preserved the caterpillar. It was colorful, with alternating stripes of yellow and black going round its trunk. Two days later it spun a cocoon Silk threads started appearing all around it until it became completely hidden from the view of the children. It was another 14 days before the children saw a white-winged moth crawl out of the silk cocoon. Another caterpillar of the same species, which the teacher brought to school, took three days to spin a cocoon which then took 13 days to become a moth. The children are now observing a third caterpillar which after 10 days has not spun a cocoon.

To help the intrinsic motivation of the children keep going, the teacher brought two booklets written for children. One book was entitled Caterpillars and the other was entitled Butterflies. The class looked at pictures of different caterpillars going through their life cycles. They saw in the book that it took one of their book caterpillars, known as the Promethea Caterpillar, many months before it changed from a cocoon to a moth. They also read that some moth caterpillars and many butterflies do not spin cocoons. They shed their skins directly and become moths or butterflies. The children are continuing their investigations and the teacher is keeping her science class going by letting children do some of the things that come naturally to them.

SECTION V:

Summary

In this section, ways in which children are very special people, and ways in which children develop, are presented and discussed.

It has also been shown how a clear understanding of the nature of children can help teachers improve their personal relationships with children, and hence improve the education which children receive at the teachers' hands.

It is important that teachers and students discuss the material presented in this chapter among themselves. It will soon become apparent that teachers have many experiences and problems in common, partly because most children respond in similar ways to similar situations. By sharing such experiences with one another, teachers can raise the status of their profession while at the same time giving children a better preparation for life in the adult world.

SECTION VI

GETTING READY FOR THE CLASS

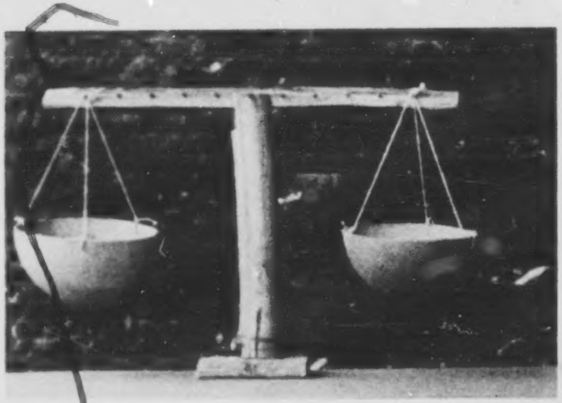
Materials

SEEDS

TORCH BATTERIES AND BULBS

A SCIENTIFIC LOOK AT SOIL

Equipment



SECTION VI

GETTING READY FOR THE CLASS

Introduction

This section attempts to give the teacher practical suggestions and help for beginning work in the classroom with an enquiry method and open-ended approach.

The first chapter discusses in some detail how a teacher might develop his own units of classroom study.

Chapter 2 concerns how to assess children's experiences in the classroom, and includes illustrations of ways of evaluation of individual children's work.

Chapters 3 and 4 present information about development of questioning skills and techniques of the teacher, and ways to help children keep records.

Chapter 1. Strategy For Unit Construction

1. Introduction

You wish to give children in your science class an opportunity to explore and experiment, record and discuss the results of their experiments, make hypotheses and verify them; in short, to carry out science investigation on their own.

Yet you recognize the need for guiding and helping them along as they gradually develop confidence in their own ideas and abilities. You need to sustain their motivation, their enthusiasm, their interest in nature and in science; and you need to do all this without imposing too much on their individual pace of learning, on their development of attitudes or on their freedom to explore and to make and verify their own predictions.

You cannot just throw a topic or a heap of materials at a class of children, say "now proceed to do science", and then walk out of the classroom. That would be foolish in the extreme. This would lead to aimless activity in the minds of the children. However, there is an alternative to the other extreme of too much direction and organisation.

Through a compromise between extreme dictation and no direction whatsoever, you can give children a clear confidence in your desire to help them as they need you, and in your concern for them to forge ahead. In other words, you must balance freedom to learn with suitable guidance in learning.

2. Unit Construction

One way in which you can study this balance is through what is called Unit Construction. A large variety of Teachers Guides, often referred to as Units, have been developed over the past several years in many African countries (see Bibliography). You may wish to refer to any one of these units, such as "Ask the Ant Lion", "Torch Batteries and Bulbs", or "Ourselves." Before you proceed to develop your own teaching unit, you may wish to analyse one or more of these units. Then try to construct a unit for yourself on some topic that interests you. The main outline of the procedure for constructing such a unit is set out below.

Choosing a Topic: Unit construction can be seen as one way of preparing lesson plans, or extensive lesson notes. The topic of the lesson can be broad such as a study of insects around the school, or more specific such as the germination of seeds. Some ways in which a topic is often selected are the following.

An interesting situation; for example, the market place, a special area of interest in the countryside such as a waterfall or a pond, or observing an insect larva beginning to pupate.

An idea or interest of a child; for example, how torches work, an interesting insect brought to class by some children, or some observations of a rainbow.

A topical phenomenon; for example, an eclipse, a sudden appearance of large numbers of insects, or the construction of a road nearby.

A scientific concept; for example, motion, balancing and weighing, or changes in matter.

A syllabus topic; for example, seeds, plant growth, mixture and compounds, or simple machines.

The reader may think of other ways of choosing a topic suitable for study by primary school children.

Developing the thread of the unit: Once you have chosen a topic, or theme for the unit, you will want to "mess about" with some of the materials in order to get an idea of the productive potential of the lead you are about to follow.

Then you may wish to construct a chain link between ideas that occur to you. Or, you may outline several ideas which radiate from your basic theme. Many of these ideas will be related to each other, forming a network of ideas which can be quite complicated. This network can be formed by posing questions and listing answers, and by showing the link between various ideas.

Developing Questions: Read about the topic chosen, and talk with colleagues and friends about the ideas so far developed; record questions posed about the topic and new ideas suggested.

List those questions which you believe can lead to fruitful activities for the children in the classroom. Those questions that appear not to lead to such activities may sometimes be used for challenging studies or discussions later on; a question may lead to more reading about the topic in library reference materials.

Analyse the questions chosen (see Chapter 4, Section V of this Handbook). You will see that many "how" and "why" questions can be simplified into one or more "what happens if" questions that at once suggest a line of investigation.

Outlining the First Few Lessons: Write out the outline of the various activities that suggest themselves from the "what happens if?" questions. (See, for example, the Teacher's Guide, "Torch Batteries and Bulbs.") This procedure up to now should give enough material for two or three lessons. It should also give an indication of the kinds of materials and apparatus needed for the activities.

Assembling Materials and Apparatus: The next step is to scout around for and collect the materials needed in the classroom, as well as to construct some of the apparatus which the children will use. Often the children are able to bring many of the necessary materials to school. There need be no serious apprehension because of limitations of time, - a crude prototype can often do the job, while some children may make considerable improvements to the original design of apparatus.

Many items can be obtained without cost if you make a point of collecting and storing used tins and jars, bottle tops, old ball point pens, etc.. Also try to interact with woodwork and metalwork teachers in your work, as well as local artisans and craftsmen.

Experimenting Yourself: With your outline written and the necessary materials collected, your next step is to do some of the activities yourself in order to see if and how well they work. This exercise is important since it may save much time later on. In addition, it will better prepare you for the variety of situations that may occur when the lessons with the children begin. Your own experimentation may lead to simplification of activities; it may reveal the existence of errors in sequence scale, or basic assumptions; and finally, it will indicate whether any of the physical operations are too difficult for young children to perform.

Writing Your First Working Draft: You are now in a position to write up the trials you have made with instructions about how to proceed and with questions arising from the trials. Details about building simple apparatus will be included. Steps in this procedure can be divided up and fit the classroom periods. This is now your first working draft.

Introducing the Unit to the Children: How will you introduce the topic you have chosen to the children? The answer to this question will depend on factors such as the previous experience of the children, your relationship with your pupils, and the nature of the topic itself.

For example, in the Unit "Torch Batteries and Bulbs" it is suggested that to introduce this topic, the teacher should see to it that each child has a torch battery, a bulb, and some wire. These materials can often be supplied by the children. The teacher then asks the children if they can make their bulb light, without giving them instructions about how to do it. In this way the teacher has immediately created a problem-solving situation for the children.

In other units such as "Exploring Nature", or "Plants in the Classroom" the teacher may take the class for a walk through the nearby countryside. Before leaving the classroom, the teacher may alert the children to look for special things, such as plants to bring back to the classroom, or nearby rock formations. Again, the teacher is trying to create a sutuation in which the children are encouraged to ask questions and to explore their surroundings.

Trying Out the Unit with the Children: Now you are ready to try out the ideas you have developed so far with children in the classroom. This will most likely take more than just one lesson. Even if you have only planned for one lesson, you are likely to find that the single lesson fans out into two, three, or more lessons as the children raise questions and offer ideas that call for further exploration and experimentation.

Some children might need the whole first lesson to become sufficiently familiar with the materials to raise questions and contribute ideas of their own. The trial should be carried out in such a way that the questions and ideas of the children form a large part of the lesson. You should be prepared to take extensive notes of the questions and ideas brought forward by the children.

Rewriting the Draft: The initial trial teaching with the children will usually lead to a rewriting of the first draft so as to incorporate the contributions of the children from the class. It would have been impossible to anticipate all the reactions of the children to the lessons you have now presented.

Trial By a Wider Audience: The next step is to ask some of your fellow teachers to try the redraft with other sets of children and give you a feedback on their trials. These trials by other teachers will increase the objectivity of your assessment of the unit. It will show the extent to which it can be taught to children in general, rather than just by you to your own set of pupils. It will also involve a greater number of persons in the general task of developing the primary school curriculum.

Writing the Trial Unit: The final step is to rewrite the unit on the basis of the feedback from other teachers working with other children. This version of the unit then becomes the Trial Unit, ready to be tried out by a larger number of teachers. The Trial Unit will be rich in variety of ideas since it has already had the benefit of several people working with it in real classroom situations.

What Teachers Do With Difficulties: In spite of several trials in the classroom, you may find certain difficulties keep recurring when the unit is used by other teachers. Some ways in which the unit can be further improved are the following.

i. Change complex questions into two or more simple questions, and then plan for more associated activities.

ii. Check to see if the intellectual and physical development of the children is compatible with the ideas in the unit. Perhaps the topic should be studied by slightly older children.

iii. Provide additional questions and explanations to accompany the activities.

iv. Record the children's verbal and non-verbal questions and examine them for hints about how to improve the unit.

v. Give more time for the children to become familiar with the materials.

3. Illustration of Unit Construction

The preceding discussion has covered several steps that might be taken when preparing activities for children in their science classes. Although this description can serve as a model for lesson preparation, there will be situations in which the science teacher may wish to emphasise some steps of the process, or may vary the order in which the various steps of preparation are treated. The important thing to remember is that the responsibility for lesson preparation rests with the teacher, and that the details of the preparation are determined largely by interaction among the teacher, the children in the classroom, and the materials or situation the teacher has provided.

It is instructive to analyze some of the materials that already exist to see how their development might have fit the strategy of unit construction described previously. It is suggested that the reader examine a variety of the Teachers' Guides that have been developed as part of the African Primary Science Programme to see how each of the stages of unit construction might apply. The following list of units might be examined as a cross-section of the materials available.

Exploring Nature
Pendulums
Ask the Ant Lion
Chicks in the Classroom
Sinking and Floating
Tools for the Classroom
Torch Batteries and Bulbs

The reader is encouraged to compare these units and their development with any other primary science materials which are available.

Activities Starting From a Clay Pot

Although a large variety of materials have been developed, many interesting topics continue to appear which might be investigated by young children. For example, it occurred recently to a certain science teacher that water kept in a clay pot is usually cooler than water kept in other ordinary household containers. Could this observation lead to an interesting science investigation for children?

What experiments might you perform initially to learn more about this question?

What materials will you need to carry out your experiments?

What are some of the questions that occur to you as a result of your first observations?

Which of these questions do you believe will be suitable for children to investigate?

Make a chart that shows the connections among the various ideas that are coming out of your experimentation. Such a chart, like the one shown in Figure 1, can be made as ideas occur to you, before all the answers are found to your questions. Many of the answers to your initial questions can come from the work of children in the classroom.

How will you introduce the topics to your pupils in the classroom? Have they observed the cooling effect of clay pots on water in their homes? Might you begin the lesson by asking them to think of the best way of keeping drinking water cool? These are the kinds of questions that a dedicated science teacher must answer. The reader is encouraged to think of other topics which might be suitable for development into primary science activities. After working together with children, over and over, in new and challenging situations, the teacher will find that this approach to primary education not only makes primary science classes interesting and enjoyable for the children, but also makes teaching in primary schools a more interesting and satisfying profession.

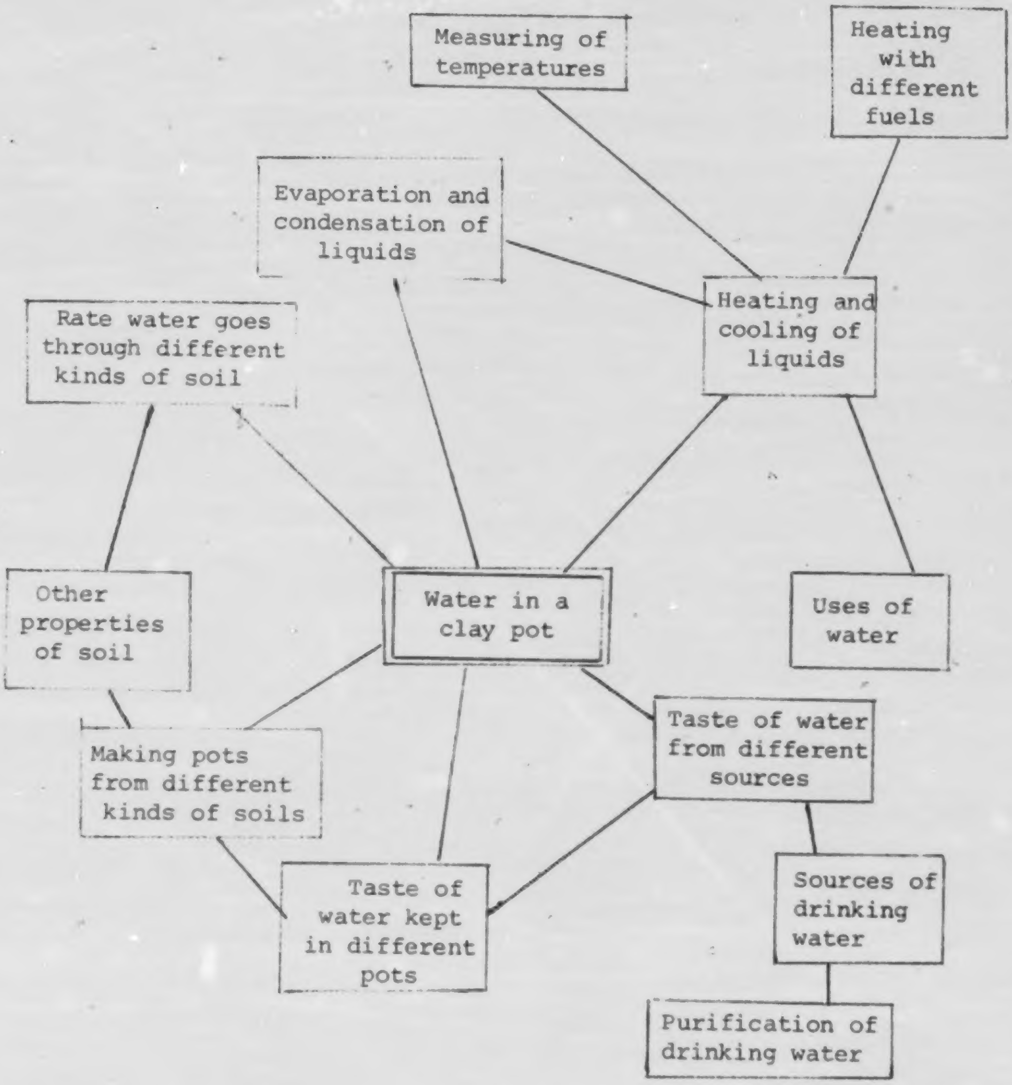

Measuring of temperatures
Heating with different fuels
Evaporation and condensation of liquids
Heating and cooling of liquids
Rate water goes through different kinds of soil
Other properties of soil
Water in a clay pot
Uses of water
Taste of water from different sources
Making pots from different kinds of soils
Taste of water kept in different pots
Sources of drinking water
Purification of drinking water

Figure 1. Flow chart showing ideas connected with keeping water in a clay pot.

Chapter 2: Assessing Children's Experiences

We will examine the question of assessment in a practical way using what we would like to call "worksheets". You are encouraged actually to work through the exercises in order to get the most out of this chapter. This is important in order to understand the full impact of the behavioural changes involved. Learning can be exhibited in various ways. It appears not only in mental skills, but also in the way children react to various situations - changing emotions, feelings, interests. These are usually regarded as being in what is called the affective domain.

There are other ways in which learning is manifested. For instance, there are the skills in manipulating, designing and modifying apparatus, equipment or even toys. Children sometimes exhibit these skills to a marked extent. Such skills are usually put in the category of psychomotor skills.

The affective domain should always be given equal prominence with both mental and psychomotor skills in testing and evaluation of children's learning. We recognize the importance of testing as an instrument of evaluation. We are opposed not to testing, but to poor testing, too great an emphasis on testing, or even making testing the most important means of evaluation.

Worksheet 1 Familiarity with questions

The problem of evaluating children's progress and work is always difficult when the teaching aims of a course change, and when the course materials demand changes of behaviour for both teachers and children. The fact that it may be difficult to find new ways to evaluate new courses is no excuse for not introducing these changes.

Read the following excerpt to see one of several approaches that have been used to help teachers become more familiar with different ways of evaluating their pupil's work.

Answer the questions asked in the following paper yourself. Discuss your answers with your colleagues. How many answers did you change after having talked about them with your friends?

EXCERPT: EVALUATION AND TESTING

When one has been involved in a project of some kind, be it personal, communal, official or otherwise, it is usually a good idea for one to "look back" and judge the value of the tasks performed. Doing this provides the mind with a frame of reference. For example, if one has been charged with the responsibility of constructing a dam from which water can be pumped to supply to a certain township population, he or she would be interested to know how well the water supply meets the demand of the population when the project is completed. One might start off by examining the rate of water consumption and comparing it with the amount of water shortage at different times of the year, and decide what to do to avoid it. This kind of assessment or evaluation is useful, for it helps in the decision making process regarding future planning.

After having worked with your pupils for say a term, you too may wish to find out what experiences they have had and what they have gained from them. Giving the children a test is the usual way of evaluating pupils' achievement. It might be mentioned here that the Guidelines for Teaching Science in Standard V also called Class V suggests certain skills and attitudes that the children should acquire as objectives of primary science education. The skills and attitudes gained should form part of the basis for examining your class. However, you may find it difficult or even impossible to examine by a written test some aspect of their education, such as, self confidence, the ability to ask intelligent questions, curiosity, or respect for other pupils' opinions. As an alternative or supplement to a written examination, you should keep a continuous record of the performance of each pupil in a form such as the following.

A. In a special notebook, set aside one to three pages for each pupil.

B. List on these pages the different behaviour traits which the primary science lessons are trying to strengthen, and leave a space to mark each time these traits are observed. The chart could look like this.

Behaviour Trait	Tallies (marks)
1. Asks intelligent questions	//
2. Makes accurate observations	///
3. Keeps neat and accurate records	//////
4. Has patience when doing experiments	///
5. Shows interest in doing investigations	///////

Thus, trait number 1 has so far been observed twice (two tallies), the second trait three times, and so on. The chart should be built up and when full a new one should be made. Continue to record on the chart throughout the year and then decide for yourself what useful information this gives you regarding the progress of each child. You may be able to think of other ways of keeping such pupils' records. The important thing is that these records help you the teacher to give your pupils the best possible education.

C. The following characteristics of behaviour could be considered together with any others you may think valuable.

1. Willingness to share one's work with others.
2. Patience and determination shown when working on a problem.
3. Originality of ideas and search for solutions to problems.
4. Offering one's opinion when in disagreement with others.
5. Willingness to change one's mind in the face of new evidence.
6. Willingness to compare one's results with that of other people.
7. Ability to keep records.
8. Ability to make accurate predictions.
9. Willingness to repeat investigations (perhaps more carefully) so as to establish validity of previous results.
10. Cooperation with other children.
11. Contribution of materials for investigation.
12. Ability to ask questions and to plan an experiment which will help to answer the question.
13. Eagerness to investigate after school.
14. Curiosity.
15. Self confidence.
16. Respect for other people's ideas.

D. In addition to these behaviour traits, you might want to describe the following:

1. The range of activities each pupil has been involved in and how well he or she worked with those activities.
2. Any special or extraordinary performances by a pupil.
3. General interest shown on science lessons.

I think you will agree with me that record cards such as these could go a long way toward contributing vital information about a pupil's progress in science. Although it may be a difficult task to carry out, it is, nevertheless, worth trying. You may find it easier to make your tally marks right after each science lesson, or even during the lesson itself. It is hoped that these record cards will help you to understand your pupils better and to evaluate their progress in science in a more systematic and useful way.

E. Returning to the end-of-term written tests, we can now see that such tests might form only part of the pupil's progress report for the term. However, written tests sometimes have their place. The kind of written tests usually given are either (1) the essay type test, or, (2) the short answer or objective type test (or a combination of both). Each of these two types has its own characteristics, a summary of which is given below.

Characteristics of two types of tests

Essay type tests:	Objective type tests:
1. Gives opportunity for candidates to show self expression.	1. Difficult to set.
2. Is relatively easy to set.	2. Easy to mark.
3. Tests for originality and organisation of ideas.	3. Easier to score accurately.
4. Difficult to mark and score accurately.	4. Can cover a wide range of topics.
5. Covers a small subject area at any one time.	5. Usually presents no special difficulties to students with language problems.
6. Can present a special problem to students with a language problem.	6. Does not allow candidate to organize ideas and put them down in essay style.

7. Difficult and time consuming for young children to write an extended discussion.	7. Does not allow for depth of description of a particular topic.

Example of the above tests:

Essay type test:

1. Describe the different kinds of seeds that you have collected.
2. Describe the behaviour of the grasshopper you have been keeping in your cages in the classroom.

Objective type tests:

1. True/False type: A bat is a mammal (true or false?)
2. Completion: Food in the onion is stored in the _________.
3. Matching: In column A is a list of words, while in column B is a list of descriptions. Next to each word write the number of the description that best fits that word.

Column A	Column B
Lion	1. Plants grow in it.
Eclipse	2. We breathe it
Soil	3. It is an animal.
Air	4. It produces a shadow.
	5. It usually sings.
	6. It flies.

4. Multiple choice: Circle the letter that contains the best answer.

   A solar eclipse occurs when

   A. The earth is in a straight line between the sun and the moon.
   B. The moon blocks off the light of the sun.
   C. The earth shuts out the light of the moon.
   D. None of the above is correct.

Whether questions are of essay or objective type, one should remember several essential characteristics of a good question.

1. Clarity. A question should not be ambiguous. The candidate should have a clear understanding of what the question is asking.
2. Suitability. The language used should be at a suitable level according to the background of the persons being examined.
3. Length. The question should be as brief as possible. Wordy questions tend to confuse children.

Think about the characteristics of a good question. In the case of multiple choice questions see if the alternatives to the correct answer (called distractors) are well chosen or whether some of them are obviously wrong. In such an exercise you might be able to appreciate the idea that setting good objective type questions is not an easy task.

F. What to Test For:

A teacher could present children with certain tasks to perform which would test for those attitudes and skills mentioned earlier which would be difficult to test for by means of a written examination. Often written tests tend to dwell on the straight recall of information though they can test for other things. However, a written test could be given in conjunction with some practical problems to solve. Thus one could test for the ability to observe carefully, to interpret data, and to think and reason in a logical way. Teachers must ask themselves what they are trying to accomplish through education in the primary school. Or, in other words, "what do I want these children eventually to become?" The answer to this question will contain aspects of learning skills, acquiring attitudes and learning certain pieces of information. These qualities of education should as far as possible be reflected in the kind of tasks presented to the children, and hence in the kind of assessment or evaluation made.

Below are some sample questions that might be given to children in upper primary classes. When thinking about these sample questions, try to establish what each question is calling for on the part of the person being examined.

1. A group of game scouts caught some poachers during the night. The full moon was shining directly over their heads. Later, when they arrived at the police station, they were asked by the officer-in-charge what time they had arrested the poachers. Which of the following answers would you give?

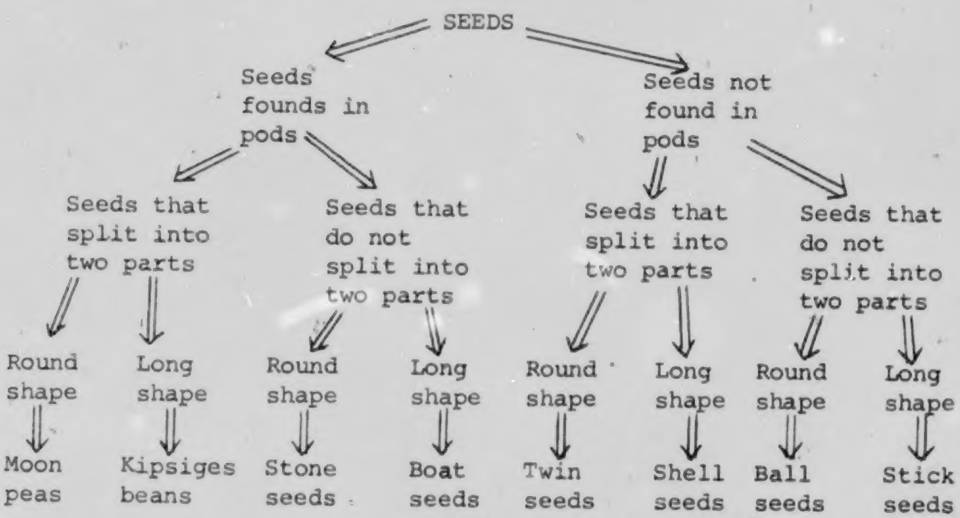
   A. 6:00 p.m. B. 3:00 p.m. C. Midnight D. 6:00 a.m.

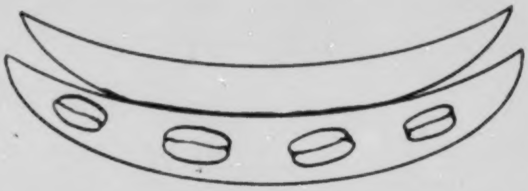
2. Some children in a primary school noticed that certain kinds of worms only come to the surface on very cool evenings. Juma says that it is because they do not like the strong sunlight. His friends say no, it is because they do not like warm weather.

   What are some things you could do to show whether Juma or his friends are right?

      Could they both be right?
      Could they both be wrong?
      How could you demonstrate whether your answers to these two questions are really true?

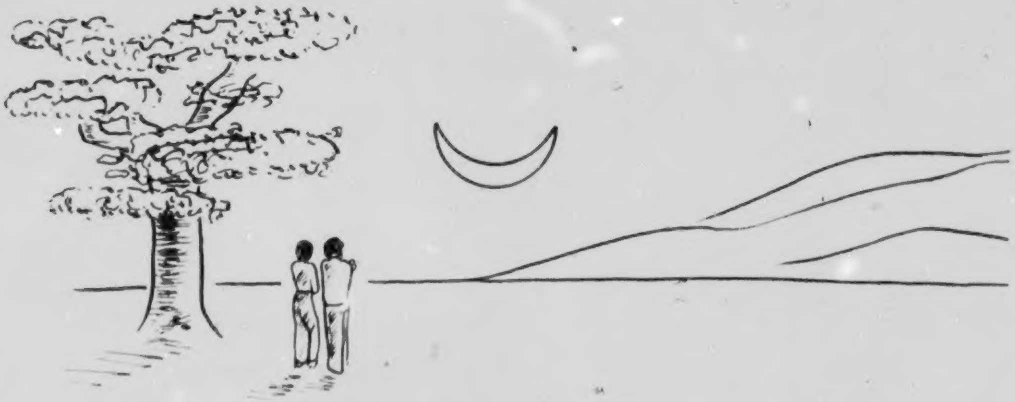
3. Children in a school near Kitale made a large collection of seeds. They invented the following system of naming their seeds.


SEEDS
Seeds founds in pods
Seeds not found in pods
Seeds that split into two parts
Seeds that do not split into two parts
Seeds that split into two parts
Seeds that do not split into two parts
Round shape
Long shape
Round shape
Long shape
Round shape
Long shape
Round shape
Long shape
Moon peas
Kipsiges beans
Stone seeds
Boat seeds
Twin seeds
Shell seeds
Ball seeds
Stick seeds



According to the system of naming seeds that these children have invented, what is the name of the seed in the drawing?

4. The moon was seen in the western sky as shown in the picture. What time was it?

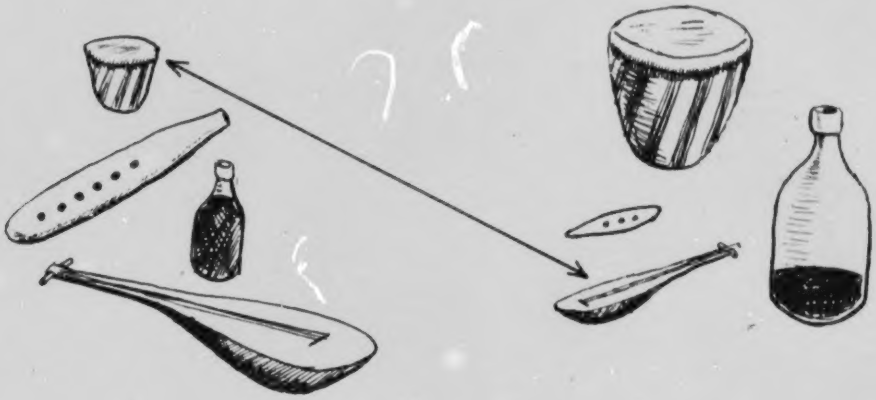


A. 10:00 p.m. B. Midnight C. 4:00 p.m. D. 7:00 p.m.

5. Some children in Standard V formed a musical group, and used the following instruments:

Instruments for blowing in	Instruments for striking
Pipes	Drums
Flutes	Guitars
Bottles	Gongs

Some of these instruments are best for making low notes, while others are better for making high notes.



A line has been drawn from the drum on the left hand side to the guitar on the right hand side. Draw a line connecting each instrument on the left hand side to one and only one instrument on the right hand side, using the information given above to decide which instruments belong together.

6. Answer the following questions:

A lion is an example of:

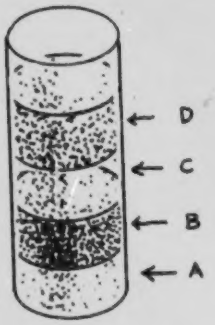
a) An omnivore; c) A dog;

b) A herbivore; d) A carnivore;

7. A likely life cycle for a moth is:

   a. egg - cocoon - larva - moth
   b. egg - larva - caterpillar - moth
   c. egg - caterpillar - cocoon - moth
   d. egg - cocoon - caterpillar - moth

8. Four different liquids were carefully poured into a tube. They made the layers shown in the diagram. The tube was then shaken. After it was left to settle, only three layers were observed. This proves that:



   a) Two liquids are nearly the same weight.
   b) Liquid A mixes with liquid C.
   c) Liquid A mixes with liquid C and liquid B with liquid D.
   d) That two of the liquids mix together.

Worksheet 2 Classifying Examination Questions

Examine the questions asked in the previous extract again. Try to decide what paricular attitudes and skills each question is trying to test. Compare the notes you have made with those made by your colleagues. To help with this task read the following extract from the Guidelines for teaching Science in Standard Five written for primary school teachers in one of the SEPA Member States.

EXCERPT: GUIDELINES FOR TEACHING SCIENCE IN STANDARD V

INTRODUCTION

As we prepare our lessons in science for the children in Standard V, it is important to keep in mind the purpose behind our efforts. As with many things we do, there is more than one reason for teaching science to young children. We can name three general goals which we would like to achieve as a result of the experiences our children will have from their science lessons. These goals are the following:

i. To help children acquire or preserve certain useful attitudes about themselves and their relationship with their environment.

ii. To help children learn certain manual and thinking skills which are useful in solving practical problems from everyday life.

iii. To help children acquire a certain amount of information which is also necessary to solve the problems we meet in modern life.

Question:

A syllabus already exists which covers a great deal of science material. Why is much time and effort being spent to prepare a new set of "Guidelines?"

Answer:

Because of the historical development of Science teaching in primary schools, most of the time in the past has been spent giving children information (see goal iii.). The emphasis should now be shifted so that goals i and ii are also given their fair share of attention.

Of course, we want children to learn more about the world around them. However, we also want them to acquire those skills and attitudes which help them to live better lives as productive citizens in their society.

Each Science lesson or activity may help to achieve one or more of these three general goals. If a lesson or series of lessons has helped to achieve all three goals, then the teacher can be particularly proud of his or her work.

SCIENTIFIC PROBLEM SOLVING SKILLS

Certain skills are needed in order to apply the scientific method to solving problems. The process of scientific porblem solving can be seen as a continuous chain through the following steps.

i. Deciding what the problem is.
ii. Collecting information, making observations.
iii. Making predictions, building a theory.
iv. Doing experiments, investigating.
v. Analysis, comparing experimental results with theoretical predictions.

Obviously, we do not consciously think about each of these steps every time we try to solve a practical problem. The approach we use to solve our everyday problems becomes a habit. It is during the early years of our lives that basic patterns of behaviour are established. Therefore, it is all the more important for young children to go through this process of problem solving. This process should be applied many times over, to problems at the children's own level of difficulty and interest. Among the basic skills necessary for carrying out this process of scientific problem solving are the following:

i. Asking Questions. Children should be encouraged to ask any questions which arise from their work. It is the task of the teacher to help the children find answers to their questions through their own observations and experiments. Instead of giving the answer directly, the teacher should help to put the children in a situation where they can find out the answers for themselves. Sometimes the nature of the children's questions makes this impossible. In this case, the teacher should either give an honest answer or wait until an answer can be found. The children should never be cheated by the teacher trying to cover up his or her lack of knowledge. Remember, no person knows all the answers!

ii. Collection of Information. All of our senses can be used to learn more about the world around us. Children should be encouraged to observe closely, as well as to listen, feel, smell, and sometimes even taste. Sometimes information can be obtained from suitable reference materials. Whatever the source, careful gathering of information often leads to new problems to solve.

iii. Making Predictions. Prediction is not the same as guessing! We make a prediction only after careful consideration of the information available to us. In other words, because we observed that certain things took place in the past, we suppose that certain other things will happen in the future. For example, if the position of the shadow of the flag pole is marked at 9:00, 10:00 and 11:00 in the morning, then the children might be asked to predict where the shadow will fall at noon. Although this process of prediction may be seen as a game, it is one of the most useful tools in the scientific method.

iv. Construction and Collection of Apparatus. As the need arises, the children should be encouraged to provide the apparatus to carry out their investigations. This can be done largely through collection and construction from locally available materials. The teacher should take part in this aspect of school science lessons in order to increase the variety of materials available to the children. (See the Primary Science Unit, TOOLS IN THE CLASSROOM). In the event of shortages of equipment, a possible solution is to divide the class into small groups and to rotate the available equipment among the groups so that all the children have the opportunity to carry out different experiments. Every school should have a "science store" in which to keep equipment not in use. In this way apparatus constructed and materials collected by one class can be used in successive years.

v. Sorting and Classifying. Children should be given the opportunity of grouping things in ways that they themselves believe are suitable. This process of sorting and arranging things gives the children valuable practice in making decisions. Once the children have had a chance to express their own ideas, the teacher may want to point out other useful ways of classifying materials. Through an orderly arrangement of collected materials, patterns may be discovered which help to solve problems or even lead to new ones.

vi. Recording of Information. Children should be encouraged to keep a record of what they do and of what they observe. These records may be in the form of drawings, charts and reports. It should be remembered, however, that a science lesson is more than a lesson in art or writing. The records the children make should be seen as part of their scientific investigations.

vii. Drawing Conclusions. Children should realise that they can learn from one another. They should be encouraged to exchange information through reports, displays and discussions. The children may use their vernacular if this is a more effective way of communicating among themselves. While working with children in Standard V, who are usually between ten and twelve years old, one should remember that children at this age are only beginning to think in abstract terms. Therefore, those thinking skills described above should be encouraged as much as possible by working in practical situations. For example, when learning about the difference in leaves, the children should collect, handle and study a large assortment of real leaves, rather than merely listening or reading about them. Although children of this age are not used to solving problems in a formal way, they will greatly benefit from the opportunity to become gradually more organised and orderly in their thinking.

FORMATION OF ATTITUDES

In order to make the best use of those problem solving skills discussed above, children should have certain attitudes about themselves and their relationship with their surroundings. Some of these attitudes are natural in young children, while others must be learned as they grow older. The task of the teacher is to try to preserve those useful attitudes which the children already have, as well as to install new ones which do not occur as a natural development. Some of these attitudes are the following:

i. Curiosity. Most children are naturally curious. Part of the teacher's job is to keep this natural curiosity alive as the children grow older. Therefore, it is important that the problems which are dealt with are interesting to the children, and that the children are able to solve these problems at their own level of understanding. The natural curiosity of young children can be one of the greatest helps to the primary school science teacher.

Remember that the teacher is not expected to know the answers to all the questions the children ask. The teacher should be aware that in scientific work the solution of one problem often brings more questions, which in turn may lead to further investigation. Thus, the curiosity of the children is an extremely important part of school science classes.

ii. Practical Approach to Solving Problems. Children should be encouraged to find answers to their questions through their own observations and experiments. If this approach to solving problems becomes a habit, then the children will be better prepared to deal with the problems they will face as adults.

iii. Self-Confidence. This is perhaps one of the most important attitudes for the successful solution of problems. Without the will to attempt to solve a problem, the problem cannot, of course, be solved. This feeling of self-confidence can be strengthened in young children if they experience many small successes and then receive approval of these successes from the teacher. Therefore, the problems the children attempt to solve should not be so difficult that they lead to frustration.

iv. Genuine Interest. If the children are truly interested in their studies and investigations, they will be thinking about how to learn more about their field of interest, rather than how to please the teacher. The teacher who has a good understanding of his or her pupils will be able to make the children feel free to say what they are really thinking, or to ask questions which truly interest them. This is made easier if the teacher is more interested in the well being of the children than in the facts that might be learned.

v. Co-operation. By working together with others in groups, children can learn to appreciate the value of co-operation. However, the teacher should try to ensure that all the children in the group participate in the activities of the group. Otherwise, some children may lose part of the value of their science lessons.

vi. Responsibility. While working together with others in small groups, each child can be given the responsibility to carry out specific tasks. For example, one child may be asked to collect as many green leaves as possible, while another child goes to look for yellow leaves. Approval from the other children in the group helps to build this sense of responsibility.

Not all of these attitudes will necessarily be stimulated by the same lesson. However, science lessons in primary school classrooms can be used to good advantage to help children acquire these attitudes. If the teacher is successful in this aspect of his or her profession, then the children will be in a better position to tackle the everyday problems they will face when they enter the adult world.

How can you determine when the child shows:

(i) Curiosity
(ii) Practical Approach to Solving Problems
(iii) Self-Confidence
(iv) Genuine Interest
(v) Co-operation
(vi) Responsibility?

Are there several ways of deciding on each of these attitudes?

Worksheet 3 Practice in Writing Questions

Writing good questions is not an easy task. Periodically throughout this course you will be asked to write questions that could be used to test the work you yourself have been doing. Writing questions and discussing them with colleagues is the best way to learn how to write good questions.

Suppose you were the teacher of the class that wrote the reports in Liquids in Chapter 1 of Section 3 of this book. Write two questions testing the work of these students. Aslo write short notes stating what attitudes and which scientific processes you are trying to test.

Discuss your questions and notes with colleagues in your group.

Worksheet 4 Assessment Other than Written Tests

There are many other ways, apart from giving your pupils written tests, that are certainly more effective ways of evaluating the success of your teaching and your pupil's progress.

Re-read the excerpt on Evaluation and Testing (Worksheet 1) in addition to the following two papers.

Having carefully read these papers, suppose you were planning to have your pupils explore some of the topics suggested in Chapter 1 of this section. Prepare materials that would enable you to evaluate continuously your pupil's progress and the success of your teaching.

Of the following two extracts the first...

Extract 1: Records

One important reason for activities is so that children can develop individually. To encourage this development, the teacher needs to be aware of the problems of each child in the class. This is why it is important for teachers to keep a record of the work their pupils have done. The records should show the range of activities that each child worked with during the term. Added to this can be a few notes to show what kinds of things each child did with the activities and any special problem a child might have, as noted by the teacher.

Some teachers keep a notebook to show the work their pupils do during the activities periods. Two or three pages in the book can be set aside for each child. At the end of the activities period, the teacher can rapidly note down anything important that happened during this period.

This is an example of records one teacher kept:

Aloys

Week 3. Worked with water and sand all week. Much time spent trying to discover how to siphon. Was early at school to make sure had plastic tube. Used siphoning in his sand play.

Agneta

Week 3. Monday, Tuesday - with water. Unsuccessfully tried to siphon.
Wednesday - with clay.
Thursday - with clay.
Friday - finds mirror. Plays with clay models in front of mirror. Looks at pictures in mirror.

Ibrahim

Week 3. Worked with clay, water and crayons. With Aloys. Clay with Ksani. Also drew pictures while looking in mirror. I drew a V and used mirror to make a diamond. He then did the same thing with different shapes.

John

Week 3. Worked with Juma and Mwalami.

There are many different ways of keeping records. Every teacher should do this in the way he or she wishes. Records should be useful and must not take up too much time to complete.

Here is another way of keeping records that some teachers have used:

	Week 1	Week 2	Week 3	Week 4
Abdu	Sand and water. With both materials experimented trying to get them to flow a long way. Used pumps and bamboo trough. Also tried Making different sounds blowing over bottles. Cardboard blocks Friday.	With Abdalla and Ali. Filled containers with different amounts. With other children trying to make water flow a long way. Crayons. Made two storey house with blocks.		

	Week 1	Week 2	Week 3	Week 4
Abdalla	Sieved with dry sand, wet sand and water. Tried to siphon. Clay modelled dog. Used tins to drum on. With blocks and stones on balance. Uncertain which side to put things on when balanced.	See Abdu. With Pili on balance. Ordered blocks in terms of heaviness. Knitted.		
Ali M.	Modelled strange clay face. Used funnels, tin with holes up the side. Trough in dry sand. Makes rattle with tin and dry sand.	With Jacob in water, used tin with holes up side as reservoir and caught water flowing out from bottom hole. Crayons. See Abdu music.		
Ali K.	Blocks, paints. Unsettled week.			
Amina.				

The following reading is taken from a Source book of suggested ways to evaluate new science programmes.

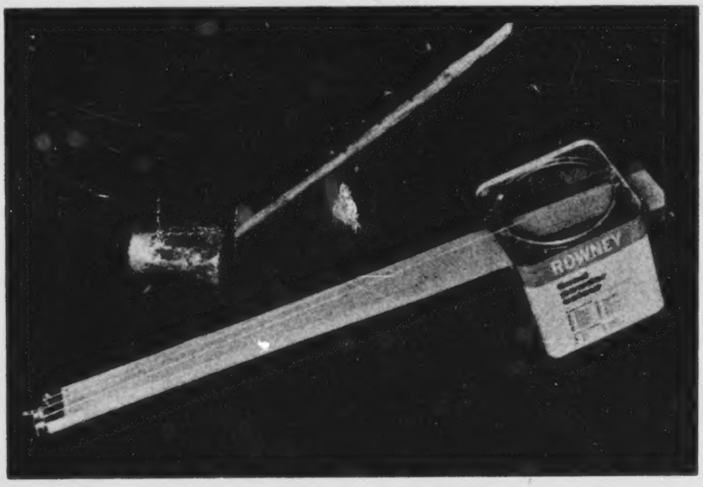
Extract 2: What you can Look for

If there is no list of facts to be followed, how can a teacher or a visitor tell whether children are gaining from their science activities?

These notes are for both teachers and visitors. The first few pages are mainly for visitors. The last two pages are mainly for teachers.

First, if the children are engaged in fruitful activities, there will be real things in the room to learn from, and they will look as if they are being cared for and used. Here are some examples.

One class might have 20 or 30 or 40 or 50 tins and containers of various sizes, with plants growing in them. This class might also have some planted outdoors. Or the class might have some hand-made musical instruments hanging from the walls or from the roof. In this class, there would probably also be some materials for making instruments - bamboo, wood, wires, reeds, tins.



A class might have boxes of sand, with insects living in them, being cared for. There might be some hand-made scales, with different things to weigh - bottle tops, stones, used torch batteries, palm nuts, soil.

There might be materials to build with - cigarette boxes, reeds, clay, wood, tins, sand. There might also be some weights to hang on the constructions, to test their strength.

In classes where the teacher has been teaching this way for one or two years, and has developed some experience and confidence, there may be materials for several different kinds of activity all at once.

Second, during the science periods, the children will be working with those materials - and not just listening to the teacher talk about them, or watching someone demonstrate with them, or writing down what someone tells them to write down. While they are working, the children will be free to talk to one another, to walk about, to go outdoors, to get materials that they need. Some may be making something; some may be using what they have made; some may be trying to do a specific thing - like making an ant lion go forward, or filling a tin until it sinks; some may be watching something very closely; some may be trying to see "what happens if,"; some may be setting up experiments;

some may be arguing about different things they have found; some may be showing each other what they have done; some may be planning what to do next.

In some classes, all the children will be trying to do more or less the same thing; in others, children will be doing many different things. Neither of these approaches is necessarily better than the other. It depends on the teacher, and it depends on the interests of the class. The important thing is whether the children are busy, know what they are trying to do, and have ideas about how to go about doing it.

If the teacher constantly interrupts and addresses the whole class, to give them further instructions, that is probably because he is requiring the children to do something in his way, instead of encouraging them to try ways that they have thought of. Similarly, if the children wait to get the teacher's approval of what they have done, that is probably because they are working for the teacher, and not for themselves. Or, if a lot of children spend their time watching what a few children are doing, that is probably because they do not quite know what to do themselves.

Third, during the time when the teacher and children are discussing what they have done, the children will be talking more than the teacher. They will be listening to each other, and asking each other questions, and giving their opinions.

The more children work in this way, the better they get at it. During the very first lesson of this sort, even the very best teacher will probably have difficulty, because the children probably will not have very many ideas of things to do; and they probably will not really believe that the teacher wants them to think of their own things to do; and they probably will not think that they should disagree with something that has been said. At first, therefore, they will probably wait to be told what to do, not make suggestions of their own, not talk to their friends about what they are doing, try to guess what the teacher wants them to say. But as children get used to this way of working, and really believe that the teacher wants them to try things in their own way, they will take more and more of the initiative themselves.

So far, you have noticed that no mention has been made of talking to the children (as an observor). One reason is that you can see the most important things just by watching - children are more likely to reveal what they know by doing, rather then by talking.

Perhaps when you visit a class, the children will be learning something else - reading, or English, or social studies - and will not be engaged in science activities. How can you let them show you what they have learned?

Not all children will have done the same thing, or will have paid attention to the same thing, so it is impossible to make up a list of questions and expect all the children to give the same answer to them. Also, some children will have learned things that they cannot say very well. They may have learned how to do something, for example, and the only way they can express it is by doing it.

Somehow, you want to give the children a chance to show you what it is that they have learned. The best way to do this, of course, is to start from the materials with which they have been working. You can ask some volunteers to tell you about the materials. If they are growing seeds, they may be able to tell you where the seeds came from and where the soil came from, and when they planted them. They may have planted them in some special way, in order to find out what happens (upside down, for instance). They may have noticed something special as the plant grew, or they may wonder what is going to happen as it continues to grow.

If they have been studying time and how to measure it, they may be able to show you some time-measures they have made, and how to use them, and why they made them that way, and what difficulties they encountered, and who thought of a way to solve the difficulty. (We hope that the children think of ways around the difficulties - and not the teacher!)

Some children will surely be too shy to show you very much of what they have been doing. You can probably learn most by asking those children who want to show you. As time goes on, and you visit more classes, see more things they have been doing, and talk to more children, it gets much easier to know what to ask, in order to get the children to show you what they know. You will also be able to recognize when some children have done something unusual - something you never would have thought of doing yourself.

You can also find out from the teacher some other aspects of the work. You can ask the teacher what has happened that he has found exciting, and what has happened that he did not expect. You can ask him what he has done to interest the children, when their interest started to decrease. You can ask him if he has ever asked other people in the community for some ideas - people like a potter or a fisherman or a builder. You can ask him whether other teachers in the school have taken an interest in what he is doing. You can ask him whether he has any reactions from parents.

So much for the visitor. What about the teacher? Even the teacher, who is with his class everyday, sometimes feels uncertain of the value of the work. Or sometimes he mav feel confident that the class as a whole is benefitting, but he would like to know more about some individual child. How can he tell whether a certain child is benefitting.

It is usually helpful to remember, first of all, the different kinds of aims we have. Some children may have made more progress in one than in another. The teacher should look not only for what a child knows, but for what he does, how much interest he shows, how much initiative he takes, how much he communicates with other children.

Here are some questions a teacher can ask himself as he watches a child's work from day to day:

1. Does he make suggestions about things to do and How to do them?
2. Can he show somebody else what he has done so the other person can understand him?
3. Does he puzzle over a problem and keep trying to find an answer even when it is difficult?
4. Does he have his own ideas about what to do, so he does not keep asking you for help?
5. Does he give his opinion when he does not agree with something that has been said?
6. Is he willing to change his mind about something, in view of new evidence?
7. Does he compare what he found with what other children have found?
8. Does he make things?
9. Does he have ideas about what to do with new materials you present to him?

10. Does he write down or draw some of the things he has done, so he does not forget what happened?

11. Does he sometimes know ahead of time what will happen if he does a certain thing?

12. Does he like to think of variation of ways of doing something?

13. Does he ever decide to do something over again, more carefully?

14. Does he feel free to say he doesn't know an answer?

15. Does he co-operate with other children in trying to solve a problem?

16. Does he ever continue with his work outside school time?

17. Does he ever bring materials to school, to investigate in the same way?

18. Does he talk about his work at other times of the day?

19. Does he make comparisons between things that at first seem to be very different?

20. Does he start noticing new things?

21. Does he ever repeat one experiment several times, to see if it always turns out the same way?

22. Does he ever watch something patiently for a long time?

23. Does he ever say, "That's beautiful?"

If a child does even five or six of these things, he is benefitting from his/her experiences in the classroom and outside the classroom.

Chapter 3: Questioning Techniques and Skills

Introduction

Asking revealing questions of nature is one of the most important skills of the scientist. Helping children to ask what is from their point of view revealing questions is one of the most important skills of the teacher. No scientist or teacher completely masters these skills. Throughout his life a good scientist thinks about the questions he asks nature just as the good teacher thinks about the way children question the world. Both of them constantly strive to improve their questioning techniques as they work. Throughout this chapter attention will be paid to those skills. Again, as in the previous chapter, the format of Worksheets is used.

Worksheet 1

Collect the following materials:

Candle, matches, jar or wide mouthed bottle, shallow dish, water, clay or plasticine.

Many people are familiar with the traditional experiment of burning a candle over water in a closed container. Fix the candle to the bottom of the shallow dish using a small piece of clay. Fill the dish with water. Light the candle and cover it with the jam jar.

Work individually for twenty minutes and write down as many questions as you can about the burning candle experiment. The purpose of this exercise is to ask as many questions as you can. Later you can decide which are good questions and which are bad ones.

How many questions were you able to ask?

Compare your list of questions with that of one of your colleagues. Work together for a further ten minutes. How many more questions can you ask?

Was working together helpful in enabling you to ask different sorts of questions?

Worksheet 2

Together with your colleagues examine the questions that you generated. Think carefully about each question and try to decide what type of question each one is. Classify your list of questions into three or four different groups.

Choose one question from each of your groups. Spend 15 - 20 minutes trying to answer these questions. Describe what you have to do to answer each question. If at this stage you think there is a need to change the way you classified your questions, do so.

Compare the system you used to classify questions with the systems used by other people in your group.

Which types of questions are best to ask when you are working with materials?

Worksheet 3 Related Readings

SEPA on Questions and Answers

One of the most vital teaching skills in Modern Science Education is stimulating children's activities by posing the right question at the right time.

This is more difficult and complex than many teachers might assume. It is a skill that must be acquired through practice and growing insight of a scientist in matters scientific (what is relevant?) with the insight of an educator in matters educational (what is relevant to this child at this stage?).

Although the classroom is the most fertile place to cultivate this ability, the problem of "asking questions" has a high priority in the training of teachers. A student who has learned to ask questions is better qualified as a science educator than a student who has learned only to give answers.

The following three papers present various ways of looking at what kinds of questions are good ones to ask. The papers deal with questions, as well as with the special way in which children can find and conserve "answers." We hope these discussions will provide some insight into the problem of asking questions, as well as some direction to set teachers on the right track.

Paper 1. Some Questions on Questions

Seeing, understanding, and stating the problem is half way to solving it. With this in mind these questions on questions are offered for the consideration of those who are most plagued by them; namely teachers.

1. At the present stage of science there are still many questions left to which there are no answers. These in themselves form a problem: children do ask such questions, e.g.:

- Where does the moon come from?
- What is gravity:
- What is magnetic?

Should the teacher avoid each question?
Should he attempt a tentative answer?
How can he communicate such problems to other science teachers?

What about those questions to which an answer is known, but which is beyond the comprehension of the children? e.g.:

- Why is melted wax transparent, while solid wax is opaque?
- What is it that makes a boy a boy, and a girl a girl?

What about the question to which there is an answer that the teacher feels he ought to know, but does not? e.g.:

- What is the difference between regular and super petrol?
- How long should a pendulum be to swing with a period of one second?

2. A record can be kept of the questions asked, and of the activities attempted to answer these questions.

Are such records useful for later analysis?
Are they useful for creating new learning situations?
Are they useful as a progress report?
Are they useful for evaluation purposes?

3. Are questions that lead to summaries of what the children have found out so far useful?

When would they be useful?
What dangers do these questions carry?
Could these dangers be avoided?

4. What does the teacher do with questions based on the past, historic events, popular beliefs, claims of "witnesses?" e.g.:

   - Mr. G. says his grandmother saw tiny dwarfs.
   - Mr. W. says he saw a snake that a certain woman had given birth to.
   - Miss H's grandfather himself heard the voices of the forest spirits.

   How do we bring the past within scientific reasoning?
   How do we deal with such problems?
   What is the evidence?
   Is the available evidence fully reliable?

   How could we check on the evidence?
   Is the claim consonant with all that we know already about the phenomenon?

5. What constitutes a valid answer?
   What constitutes a fertile answer or question?
   What constitutes a sufficient or adequate explanation for a child?

Paper 2. Teacher Training Ideas on Developing Questioning

Towards the end of 1969, there was a general feeling among the tutors in the Department of Science Education, College of National Education, Morogoro, that the second year students were not yet very skilled in the art of asking and handling questions. That is, what kinds of questions are appropriate to ask children and when should they be asked? The best kind of question is one that can be answered by the children by using the materials with which they are working. We knew that the student teachers had been involved in New Science for almost two years and their tutors had tried to use the right form of questioning during this time. In spite of this, the students' standard of questioning was not entirely satisfactory, although a few of them were quite good at it. As was seen during the students' practice teaching outside the college and during micro-teaching within the college, most of the students needed to improve their way of asking and stimulating questions. Our job is not to prepare just a few students but to prepare as many as possible. In order to solve this problem, the author decided to involve the students in:

a) questioning exercises,
b) classifying their own questions,
c) assessment of their own questioning,
d) testing their own improvement after passing through a), b) and c).

To do this effectively, a situation rich in many different possibilities was to be chosen - a very open-ended situation. It should be presented to students in such a way that they all know what is required of them. Seeing possibilities in a given situation and asking questions that will stimulate further learning was the desired goal. To satisfy these needs, "burning candles" was the topic chosen and presented to the students.

. . . .

The students did this exercise for fifty minutes. Their manuscripts were collected and evaluated by the author. When it seemed necessary, these manuscripts were also evaluated by two other tutors.

. . . .

After going through the students' manuscripts, we made a few interesting findings about ourselves as tutors as well as about the students.

. . . .

... (and) what was considered principally a means of teaching about questioning turned out to be an excellent way of assessing the students...

Questioning

... the author wanted to teach about the art of questions in the way he tries to teach about New Science - experimentation, discovery, re-thinking and personal involvement. This is not possible without open-endedness, which is always accompanied by unexpected things ... In this case, the unexpected thing was our discovery of a way in which we might assess our students. Nevertheless, the art of questioning was effectively dealt with as well. Briefly, this is the way the author went about it.

The questions were divided into four groups:

Group A: "Do and see" questions, or "What will happen if...?"

Group B: "Why" questions, which, if broken into smaller "do and see" parts, could be answered by using the materials provided. ...

Group C: "Why" questions whose immediate answers can be found on the spot, but which lead to more questions that cannot be answered directly using the materials provided. ...

Group D: Questions whose answers require definitions. ...

. . . .

During the next science period, the author held a class discussion on the types of questions drawn from the students' manuscripts. The questions were written on the blackboard and the students were required to answer, using the candles and the other materials provided. They were told that they should try to answer at least one question from each group. They worked hard on this and it was a good lesson for them.

. . . .

All the questions in Group A could be answered directly by the students using the materials provided. (For example, "how long does it take to burn a candle one cm. long?") However, it was felt by the students that under some circumstances, some "why" questions like those in Group B could be put into Group A. During the class discussion, students found out that some "why" questions ... can be answered on the spot using the materials supplied, provided the learner has previously gathered enough supporting evidence from his experiments. ... (With some questions), they found out they could do nothing to answer the question unless they broke it into parts. For example, what will happen if ...

. . . .

The students found out that no matter how they broke up the questions in Group C they would not be able to answer them on the spot by using the candle. ...

When they tried to answer the questions in Group D, for example: "What is the origin of the candle?" or "What is a candle flame?", they found it was impossible to answer them by using the materials supplied. Something outside the situation supplied was needed to answer such questions. They also agreed that asking such questions is similar to asking for definitions. However, good questions for primary school science demand that it should be possible to answer each question by using the situation and materials supplied.

It was pointed out that all the questions put on the blackboard were drawn from the students' manuscripts. They had been asked to ask questions that could be answered on the spot by using the materials or the situation supplied. The students were then asked which group or groups of questions could be answered on the spot using the situation supplied. They were asked to arrange the groups of questions in their order of suitability. Nearly all the students came up with one of these two orders: A, B, C, D, or A, B, D, C. They all agreed that the best questions were in A, and that the poorest were in either C or D. They agreed that questions in either C or D should not be asked by any teacher in a New Science class. (Although no rigid rule should be made about this, the teacher should take great caution when using such questions in the classroom.) ...

It was found that students are able to discover good and bad questioning if they are given the opportunity to do so. They learnt how to use the situation provided to test the suitability of a question. They started testing the suitability of their own questions in their manuscripts. Then they modified those questions. They did not condemn all the "why" questions. Some "why" questions asked under some special conditions could be included in Group A (the group recommended by the students to have the best questions). These "why" questions are the ones that sum up some experimental evidence. ...

Mention should be made of the fact that the students were involved in New Science up to the last day of their stay in the College. Their activities were normal science activities only and the students felt that they were doing their usual work. There was no examination panic. There was no need for this because there were no facts to be tested. Rather, we were testing their ability to do science. Most of our students became confident that they can do science, though of course some are better than others.

Paper 3. Between the Question and the Answer*

What is a good question? Recognizing a 'wrong' question is one thing; how to ascertain the 'right' question is quite another. A good and healthy question is one to which there is an answer, because it is a problem to which there is a solution. The right question is a stimulating question which leads to a closer look, a new experiment, or a fresh exercise. The right question leads to where the answer can be found: in the real objects and events under study, where the solution is hidden. The right question asks the children to show rather than to tell the answer: they can go and make sure for themselves.

Such questions I would like to call 'Action Questions' because they stimulate productive activity. There are action questions of various sorts ...

The first, and simplest, kind of action questions are the straight forward "Have you seen ...?" or "Do you notice ...? type of questions.

...

Questions like "How many?", "How long?", "How often?", and their like are measuring and counting questions. The children can check and make sure of their answers themselves. They can use new skills, and feel content and confident.

---

*Extract from "Between the Question and the Answer" by J. Elstgeest (in press)

The "What happens if ...?" questions always work, because they can always be truthfully answered. They entail simple experimentation, and never fail to provide a result. These questions are particularly valuable in the beginning of a new scientific study to explore the properties of unfamiliar materials, living or non-living, or forces at work, and of other eventful happenings.

- "What happens if you place your ant lion in damp sand?"
- "What happens if you pinch the seed leaves off a young plant?"
- "What happens if you turn your twig (cutting) upside down in water?"
- "What happens if you spin a bowl full of sand?"

There are millions of other good examples of "What happens if ...?" questions which have millions of other answers that can be readily found to the satisfaction of the children and their teachers. These questions always show some form of a relationship, and greatly add to the store of experience which young children require. ...

After sufficient activities provoked by the type of questions just described, children become ready for a new kind of question: the more sophisticated "Can you find a way to ...?" question. This will always set up a real problem solving situation to which children enthusiastically respond, provided it makes sense to them.

I once asked a class of children: "Can you make your plant grow sideways?" Since they had studied growing plants (which they kept in tins, pots, and other contraptions made of banana sheaths) only a short time, I was just a little too hasty and anxious, and quite rightly got the answer: "No, we can't." So we patiently continued with scores of "What happens if ...?" experiments. Plants were placed in wet and dry conditions, in dark and light corners, in boxes and in cupboards, in collars of white and black paper, upside down and right side left. In other words, the children made it difficult for the plants. But the plants never failed to respond in one way or another. Slowly the children began to realize that there was a relationship between the plant and its environment which they controlled. Noticing the ways in which the plants responded, the children became aware that they could control the growth of plants in certain ways, because the responses of the plants were shown by the way they grew. Tips curved upwards, stems bent, plants grew tall and thin, or sometimes withered altogether.

When later the question "Can you find a way to make your plants grow sideways?" reappeared, there was not only a confident reaction; there was a good variety of attempts, all sensible, all based on newly acquired experience, and all original. Some children laid their plant on its side and rolled a newspaper tube around the tin and the plant; others manufactured a stand to hold a horizontal tube into which they pushed the top of their plant (this one turned back!). One group enclosed their plant inside a box with a hole, but they fixed a tube in the hole and directed it toward the light of the class window. Some just tied their plant sideways along a cross stick, and added restricting strings as soon as the growing tip curled upwards again.

It is obvious that "Can you find a way ...?" type of questions must be preceded by satisfactory exploration of the material with which the children work. The children need to investigate first what the possibilities and impossibilities are, and become familiar with some of the properties of the objects under study.

Lastly, there is a category of questions which we should approach with the greatest caution, for there is a serious danger of misusing them. They are what I call "Reasoning Questions". These, too, may begin with "Why?" or "How?" and that is where the danger lies. However, they are very important, and Modern Science Education could not eliminate them without defying its own purpose. But we can and must eliminate the "one right answer". Reasoning questions are meant to make the children express freely what and how they think about their observations and study. The discussion, the dialogue, the sharing of ideas, often help in recognizing relationships, and aid understanding. It is essential that the children talk freely, for even the most preposterous statement can provoke argument, and argument leads to correction, provided it is based on evidence.

The teacher must be very careful how he phrases these questions, and when to present them. Children working with mosquito larvae for the first time may be effectively put off from any further exploration, if they are pestered by a sudden "Why do the larvae come to the surface of the water?" On the other hand, children who have watched mosquito larvae wriggle down time after time whenever they were disturbed by a waving hand, by a knock on the jar, by shaking or stirring the water; children who have watched the larvae come up again and again; who have noticed their tail tubes sticking out of the water; who have timed how long they stay under the water level; who have tried to prevent them from coming up by continuously shaking or knocking the jar; who have covered the top of the water with snippets of paper or cellophane; and have noticed the persistence of the larvae to reach the surface; only those children can become involved in a sensible argument when asked: "Why do you think the larvae come to the surface of the water?" Those children can express their thoughts with confidence, because they have something to think and to talk about; because they can produce relevant evidence. And do not think that "because they want to breath" is an obvious answer. It is not. Many water creatures never do it, and a tail is not readily associated with breathing.

There are a few more aspects to the why-question, which are useful to be considered here. We cannot avoid why-questions, for children are great why-questioners. We should not avoid them, because "Why?" is the ultimate quest of Science. What we should avoid is confusing the children with both "Why's" and "becauses". Parents as well as children have come to regard teachers as encyclopaediac. This flattering attitude, erroneous though it is, tempts many a teacher to answer questions he is asked. ...

The truth is that many "why" questions have not yet been answered. No teacher in the world is able to provide a ready answer to all the questions asked by the children. There is nothing wrong when the teacher honestly admits that he does not know the answer. The reason may be that he just does not know, or that the answer is unknown to everybody. Both reasons are perfectly valuable.

... Science is the search for, rather than the answer to WHY? WHY? is the ultimate question, and the reason for all science committed in the world. WHY? is the most elusive question. As soon as we think we are approaching the answer, we are back in the desert, and a new WHY? shimmers above the horizon. Mankind has not yet found a single final answer to a single final WHY? Why things are the way they are is unanswerable. Why things work the way they work may be answerable, provided the answer to "how" is found. So the search continues, and it is into this search that we introduce our children. Their simple science, too, is a living part of the incessant quest toward "because", and every new relationship that they can establish brings them nearer to the ultimate answer, but only by one step.

These steps are essential. We cannot jump, neither should we expect our children to jump. "Jumping to conclusions" has always been condemned in scientific circles. Even adult understanding of "because" depends on their own step by step progress through masses of experiences, together with their ability to correlate these experiences. Many of us have understood things that we were supposed to have "learnt" at school, only years after we were set free to educate ourselves.

...

A good question is more important than its answer. Not only because science sits between the question and its answer; a good question often leads to communication between the teacher and the children. Communication is a vital aspect of the process of science. However, communication means dialogue. It can take various shapes, but it never takes the shape of a teacher dictating summaries, nor of a child chanting obedient answers.

Worksheet 4

Learning how to ask good questions of nature is one skill. Asking children good questions requires different techniques.

Re-examine the questions asked when your class was working with candles. Try to decide which questions would be good questions to ask children. Why do you think that the questions you have selected are good ones to ask? You might have several reasons. The only real test of course is to ask children and find out from the way they react whether or not the questions really are good. This could be done by working with a class of children. However, this is not always the best way to examine and improve one's questioning skills. It is possible to work with very small groups of children and analyse what is happening in greater depth.

B. Activities with children

- Select any suitable topic from the school science syllabus e.g. soil, plants, insects.
- Design a problem on which your pupils can work.
- Pupils should record their information.

- Hold a discussion following their investigation and note down as many kinds of questions which they ask as you can.
- Give the pupils a chance to think of ways of seeking solutions to their problems and, if they are unable to do so, make the necessary suggestions for further investigations yourself.

Example

Children have been working on different kinds of soil. Here are some of the questions they ask:

1. How many different kinds of soil are there?
2. Why does sandy soil allow water to pass through faster than red soil?
3. Why are there bubbles when water is added to soil?
4. Why does water mix with soil but not with cooking oil?
5. Why do we have soils of different colours?

Suggested ways of handling the questions

Question 1: It may not be meaningful for you to tell children that we have clay, loam and sandy soils. Instead you could assign children to collect as many different kinds of soils as they can.

Question 2: Speaking of particle size might be a start. However, you should let the children find out which kind of soil (e.g. the ones collected in Question 1 above) retains more water than the other - which retains least/most (and thus which allows most/least amount of water to pass through it).

Question 3: If the pupils have studied air then they might understand that there is air in the soil. However, it would be a good idea for the children to estimate how much air e.g. by counting bubbles and/or by the usual way as contained in text books.

Question 4: This is a difficult one for children to find a solution for, as the idea of immiscibility is not easily comprehensible to them. However, they might think of investigating what other liquids besides water mix with soil.

Question 5: Again this is a difficult one for the children to find solutions to. In fact it is impossible for them to design an experiment to find out *why the different colours*. However, as they carry out the suggested *further activity* in Question 1, they could at least collect a variety of differently coloured soils.

It is of great importance for children to appreciate the limitations to and extent of their abilities to "*discover*". However, every necessary help and encouragement to search for solutions to their problems, should be given to the pupils. Through constant investigation and asking of questions followed by further investigation, it is hoped that the pupils will acquire among other skills, the ability to look at their environment more critically.

Chapter 4: Keeping Records

If you have already done student (or practice) teaching, you probably have come across situations in which pupils should have kept records of their observations but did not. For various reasons, children very often will not keep records. One reason (as you learned in the section called Relating with Children) is that they have not yet reached a stage where they realise they should keep records. Very often, too, even when they have reached the stage when they see the necessity for making records, they cannot make good records.

At several places in this Handbook, your attention has been drawn to the need for you and your pupils to record observations. In Section V you twice came across conversations which were recorded by an adult. Take another look at them to see how complete they were and how well they conveyed their message to you. Now take another look in the same Section at the place in Chapter 4 describing a ten-year old who rebuked himself for not remembering the intensity of the light and note how he solved his problems. In Section IV you also can see records of observations made by pupils and by their teachers about their activities.

In Section II you read examples of records of observations made by teacher training college students during their observations of various phenomena, e.g. the solar eclipse and the behaviour of rubber bands. Records of the behaviour of liquids and those on relations and functions were made in Section III. All of these records were different in flavour:

i) the adult recorded the conversations word for word;
ii) the ten-year old kept in his pocket those items he needed again to produce light;
iii) the teacher at Juba beach kept a written record of her children's activities whenever they visited the beach;
iv) the pupils kept records of their observations whenever they visited the Juba beach; they kept at least two types of records. Can you name them?
v) the students' record on the solar eclipse also employs different methods for different purposes. Try to identify the different techniques and some of the purposes they serve;
vi) with regard to relations and functions, additional types of records were kept and they led to special types of understanding of observations. It was also in this Section that you made pictorial records other than photographs or drawings.

These records were kept for various reasons. The ten-year old at Awo Omama wanted to have an accurate record with which to make a comparison. You could list some of the reasons for the records described in i), iii), iv), v), and vi) above.

By now you have noticed that there are different ways of keeping records. Consider one teacher's record on one lesson when his pupils had been learning about blood circulation:

*T. What to you know about the heart?
P. It pumps blood.

---

*There were fifteen pupils in this group

P. It beats. It beats harder when you are afraid.

T. How fast does it beat?

There was a discussion at this point on how one can count the pulse rate, where to feel it, and which fingers to use. The pupils worked in pairs with each member of a pair counting the partner's pulse rate. After they counted the pulse rates, I asked them to give their results and I wrote them on the blackboard this way:

Pupil	Rate	Pupil	Rate	Pupil	Rate
(1)	79	(6)	120	(11)	84
(2)	60	(7)	88	(12)	76
(3)	82	(8)	76	(13)	77
(4)	78	(9)	82	(14)	80
(5)	83	(10)	69	(15)	66

I continued:

T. Now, what can you say about the pulse rate?

P. They are different.

T. But what can you say about the pulse rate of all of you?

P. Everyone has a different pulse rate.

T. Can you say what the highest pulse rate is?

P. Yes, 120.

T. What else can you say about the pulse rates?

P. The lowest is 60.

P. Can we use the average?*

T. Yes, what is the average pulse rate for all of you?

The pupils calculated the average. Then I asked them: Does the pulse rate ever change? There was a long discussion which ended with the pupils deciding to run a distance and then counting their pulse rates immediately after the run.

In subsequent lessons the teacher allowed the pupils to run the distance and to notice that the pulse rates of most of them changed. They also had opportunities to find out if the pulse rate would continue to increase when one runs a very long distance. They experimented over distances of 40 yards, 60 yards, and 100 yards, and kept records of their pulse rates. Then they went on to examine a sheep's heart as well as photographs of the human heart.

---

*Pupils had learned about averages in their mathematics lessons.

To return to the numbers written on the blackboard by the teacher and to the pupils' comments on them, notice that they do appear very different. Do you get any more information by arranging them from the largest to the lowest?

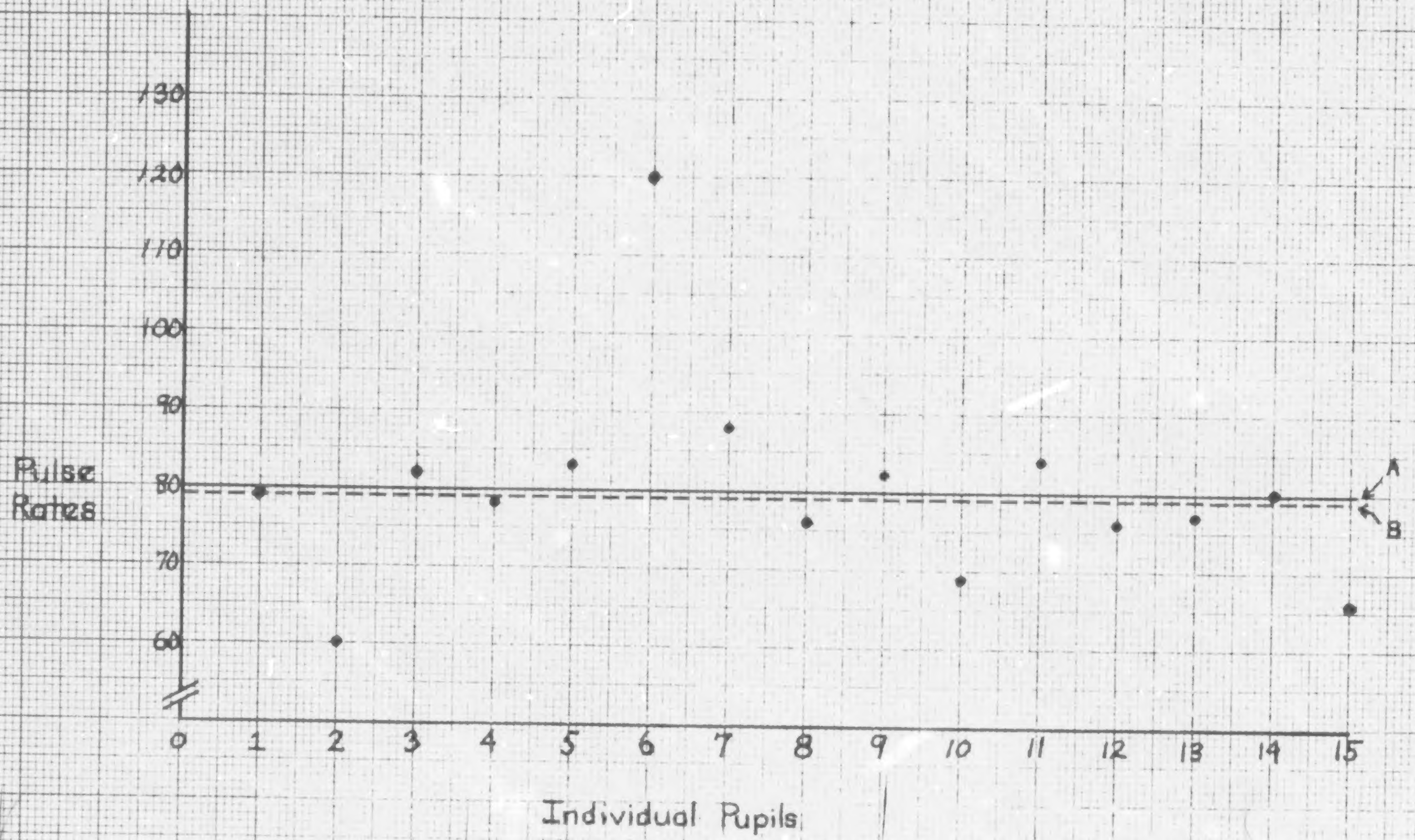
The following graphs are three ways of describing the pulse rates of the fifteen pupils (see next three pages for graphs). Each of them gives you a pictorial account of the pupils' pulse rates. When you look at each of them, what strikes you immediately? As you study them further, try to answer the following questions using each graph:

a) In which one is it easiest to see the lowest and the highest pulse rates?

b) In which one is it easiest to see the pulse rate shared by the largest number of pupils?

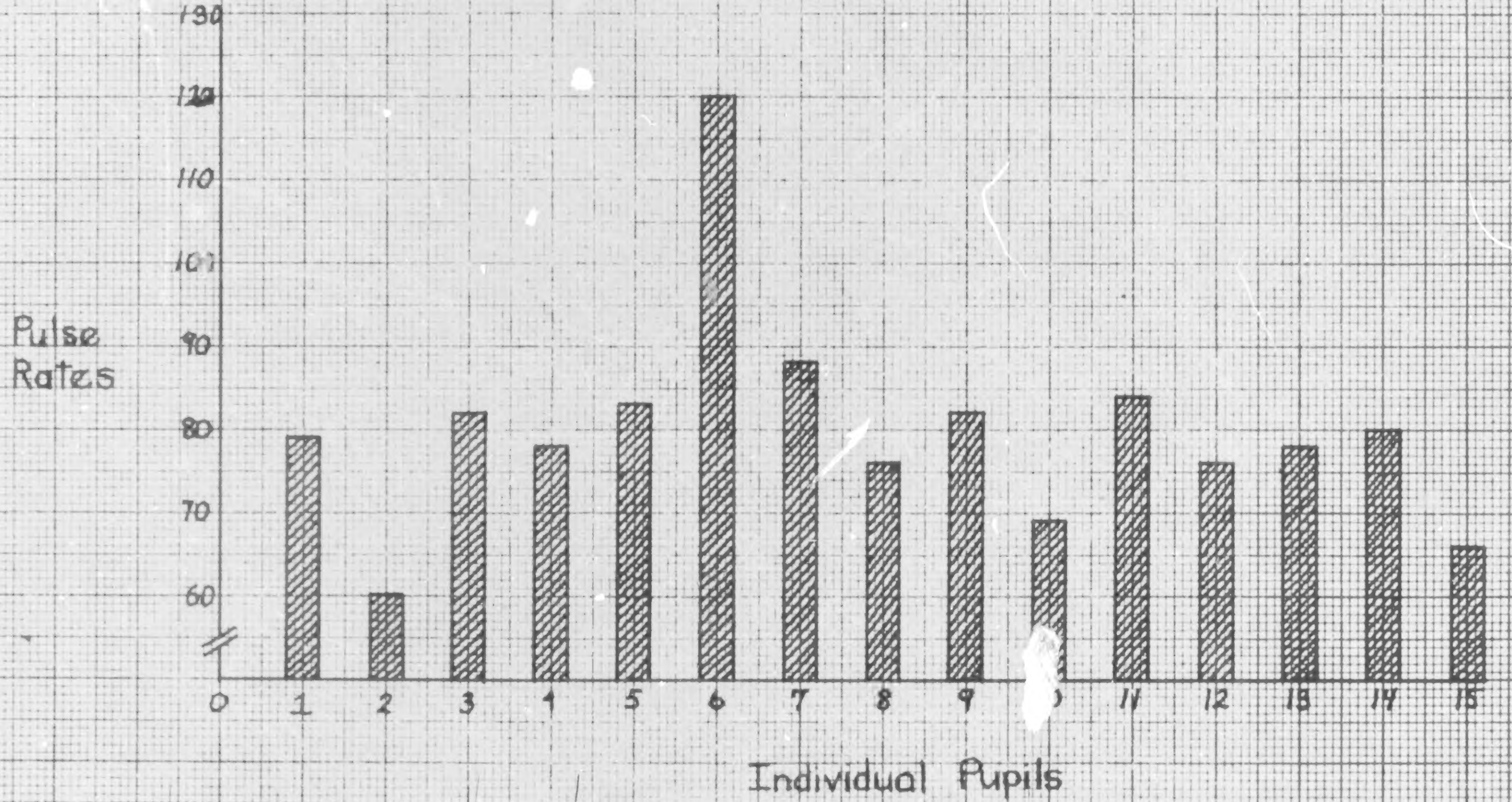
c) Which one shows the average pulse rate for this group of pupils most easily?

d) Which graph shows most readily the pulse rate below which exactly half the pupils fall?

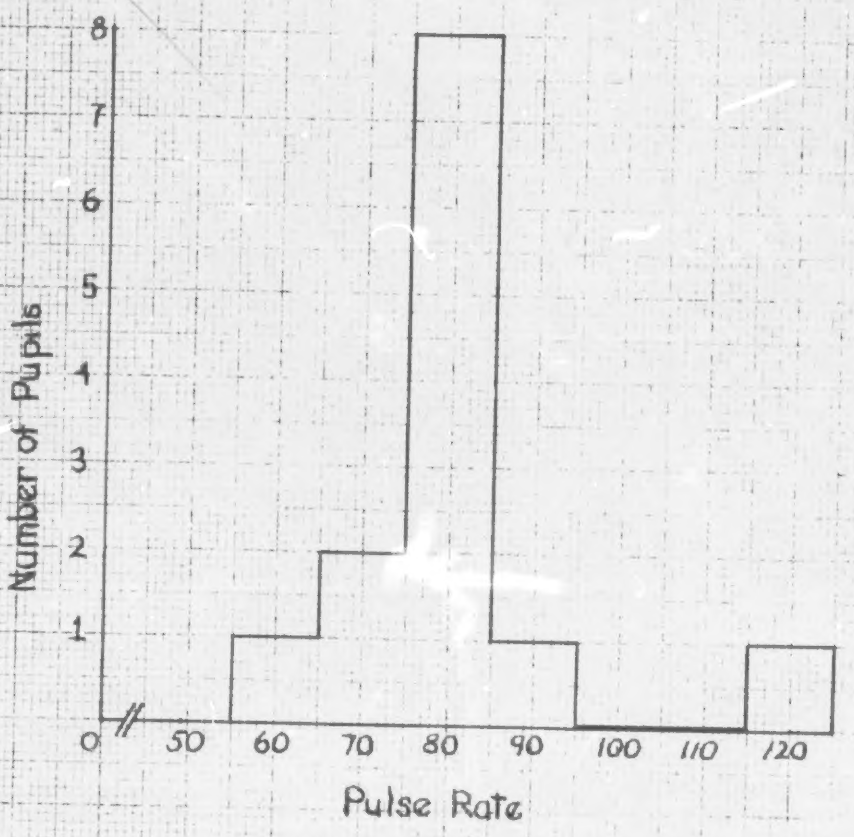


Pulse Rates
130
120
110
100
90
80
70
60
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
A
B
Individual Pupils

I


Pulse Rates
130
120
110
100
90
80
70
60
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
Individual Pupils

II


Number of Pupils
8
7
6
5
4
3
2
1
0
50
60
70
80
90
100
110
120
Pulse Rate

III

e) Which of these graphs would you use if you wanted to see very quickly the number (or numbers) which would be representative of most pulse rates in this group of pupils?

There might be other questions you can answer using these graphs and some might be easier to answer using one graph and others might not be easy to answer even when you use all three graphs. You might have questions about the graphs themselves: What are the differences among them? What are the similarities? Are there other types of graphs that can make it easier to find answers to your questions? How does one learn to make a graph? Your tutor might help you to find out more about graphing if you ask for his guidance.

In this chapter your attention has been drawn to various ways of making records of observations. Some ways are useful in some instances and other ways are suitable for other types of observations. Very often, the type of record to be made depends on one's aim and also on the type of information to be gathered. You may wish to improve your own skill in making records so that you can later guide your pupils most profitably. For your practice, a number of suggestions are made.

Worksheet 1.

When you next go to the market make note of its area, the number of people, the number of girls, the number of boys. You can go to the market twice in a day to make these observations and you should also go on different days. Record your observations in various ways to reveal the following:

i) the arrangement of stalls in the market;

ii) the different commodities sold at the market;

iii) the average number of people visiting the market at one time in a day;

iv) the average number of boys and girls at the market at one time in a day;

v) the average number of boys and girls at the market on Saturdays and the average number on any week day;

vi) the most popular day at the market;

vii) the least popular day.

Worksheet 2

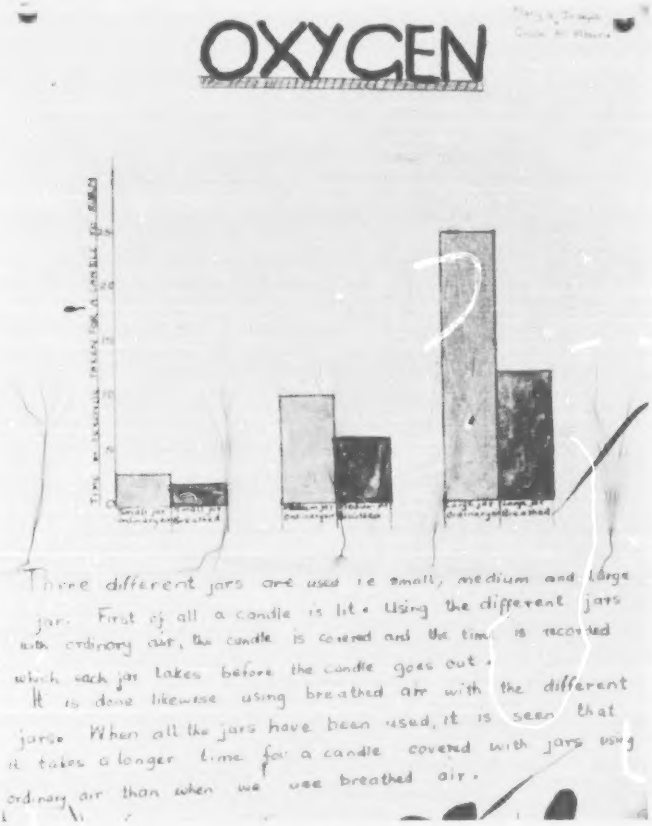
When you visit the grains section of the market, note the different types sold (e.g. maize). You may select one or more of them and find out if all the seeds are alike; can you tell in what ways they are different? How many of each type are in each sample you have? Obtain ten samples and record information on them in different ways.

In addition to, or instead of, doing the activities described above, you can decide to do others which are of more interest to you. They, too, will give you practice in making meaningful reports.

While it is very important and interesting to make records of one's observations, it is more important that the child should feel the need to make them. Children's learning and enthusiasm can be disturbed seriously if, while carrying out investigations that are of great interest to them without keeping records, the teacher forces them to make records. When they see the need for keeping records, children are usually willing to repeat exciting investigations.

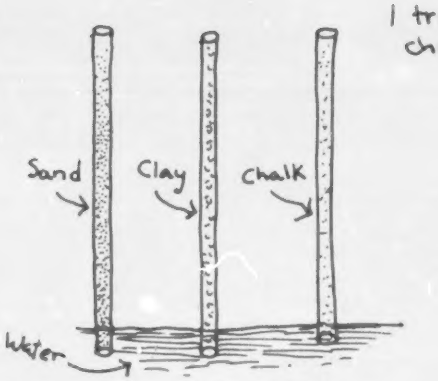
Finally, what you learned about the children's limitations in Section V and under "Questioning Techniques and Skills" applies also to the teaching of children to keep records.

THESE ARE WAYS THAT SOME PUPILS AND TEACHERS HAVE KEPT RECORDS

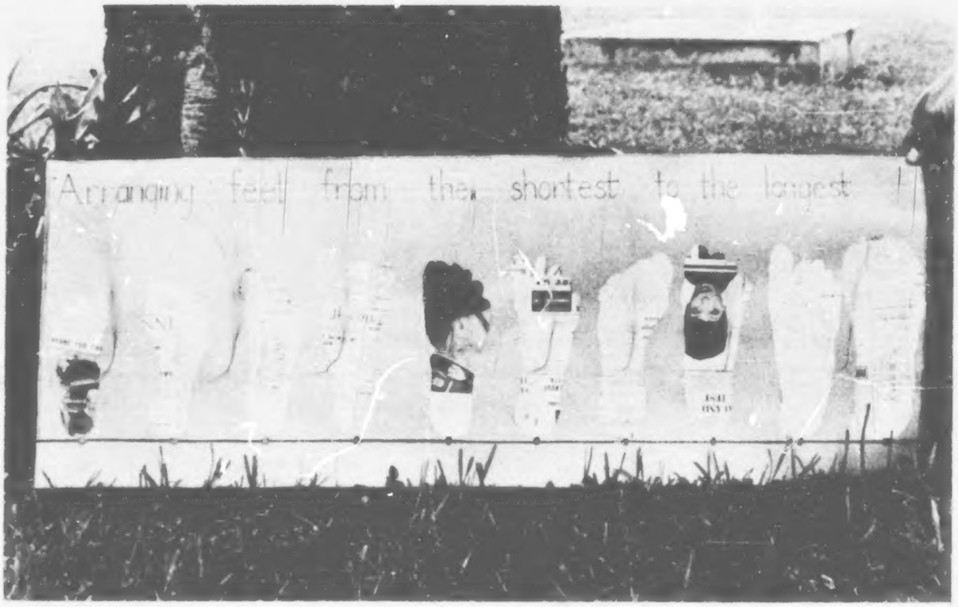


Three different jars are used ie small, medium and large jar. First of all a candle is lit. Using the different jars with ordinary air, the candle is covered and the time is recorded which each jar takes before the candle goes out. It is done likewise using breathed air with the different jars. When all the jars have been used, it is seen that it takes a longer time for a candle covered with jars using ordinary air than when we use breathed air.

I tried to put sand, clay
chalk in BIC TUBES


Sand
Clay
Chalk
Water

In Sand water can rise up very quickly
and in clay it cannot rise very quickly it rises slowly
and in chalk water also rises very slowly.


Arranging feet from the shortest to the longest

SECTION VI:

Summary

While Section V treated some of the philosophical issues connected with the nature of children and their development, this section has given some practical suggestions about how to prepare for the classroom and how to proceed when in the classroom. Both a clear understanding of the underlying principles of child development and a knowledge of how to apply those principles in a practical way to a real classroom situation are necessary in order to give children the best possible science education.

Methods of evaluating what is happening to children through their science experiences have been discussed. The basic aim of such evaluation techniques is to help the teacher decide how to improve continuously the science lessons in his or her classroom.

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To make use of APSP units in the pre-service training of teachers, tutors of training colleges will require some background material to amplify certain aspects of some units and to extend the possibilities of others. Some of these resource materials may even provide ideas for developing new units within the framework of the APSP spirit of learning.

The references which are listed below are grouped into four areas. Those which are of general nature in relation to the Enquiry Method of science, indicating what other organizations have done in this respect. The other three areas refer specifically to the APSP units classifying them into biological, earth and physical science-oriented units.

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Section B

Biological Sciences

APSP UNITS

Ask the Ant Lion
Buds and Twigs
Chicks in the Classroom
Exploring the Local Community
Juba Beach
Mosquitoes
Ourselves
Plants in the Classroom
Seeds
Small Animals
Tilapia

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Section C

Earth Sciences

APSP UNITS

Exploring the Local Community
Exploring Nature
The Moon Watchers
A Scientific Look at Soil
Star Books: Stars Over Africa
Strangers in the Sky
Using the Sky
How the Sky Looks

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Section D

Physical Sciences

APSP UNITS

- Arts and Crafts
- Balancing and Weighing
- Changing Solids
- Chima Makes a Clock
- Colours, Water and Paper
- Common Substances Around the Home
- Construction
- Construction with Grass
- Cooking
- Copper Activities
- Dry Sand
- Estimating Numbers
- Friction
- Inks and Papers
- Liquids
- Making Paints
- Making Things Look Bigger
  - Making a Magnifier
  - Making a Microscope
- Measuring Time - Parts I and II
- Pendulums
- Playground Equipment
- Powders
- Printing
- Sinking and Floating
- Tools for the Classroom
- Torch Batteries and Bulbs
- Water
- Wet Sand
- Woodwork

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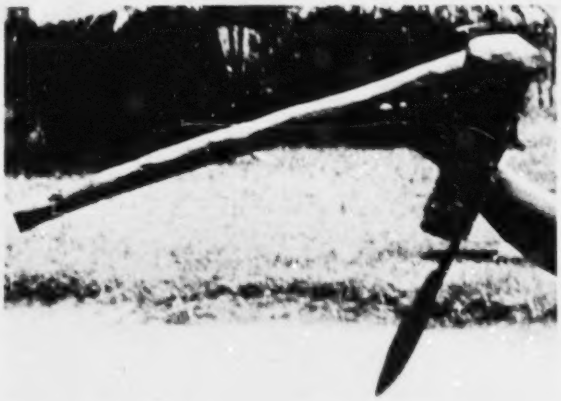
Acknowledgements:

Our thanks are due to Mary Jane Neuendorffer for editing the manuscript, and to Barbara Morse, Seth Daflagbe and Aning Gyamfi for typing it.

EXPLORING THE LOCAL COMMUNITY: VILLAGE TECHNOLOGY

TOOLS

BUSH ROPE



SPINNING COTTON

MAKING POTS